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Make way for the 16-core, 32-thread monster **PG. 76**

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Perfect projects to get the most from your Pi **PG. 34**

THE STATE OF VR
Is it really the future or just a passing fad? **PG. 46**

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GEAR OF THE YEAR

PLUS!
Build a **$2,200** VR machine for Half-Life: Alyx
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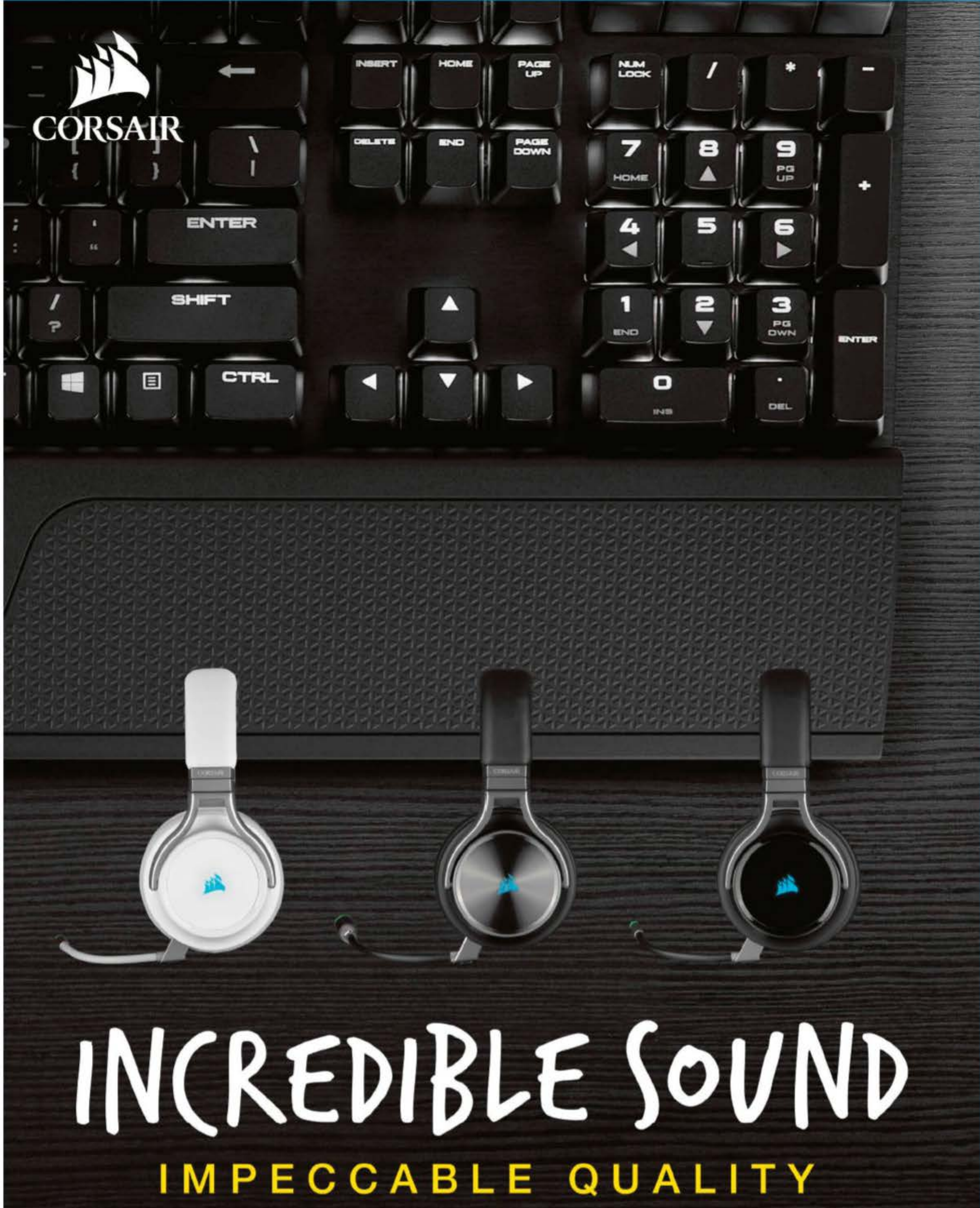
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Alan Dexter

THE YEAR IN REVIEW

CLOSING THE YEAR by looking at the best hardware from the past 12 months is a great way of seeing how far we've come, and this year is no different. The constant march of progress means that a PC that you build today is going to be notably more powerful than one you could have built a year ago, and this year that machine is more likely to be built around one of AMD's Zen 2 chips, with their abundance of cores and support for the latest PCIe 4.0 speedy NVMe SSDs. That hasn't been the only advance, though, so turn to page 24 to see the gear that wowed us the most.

Our other big features include the best projects for the Raspberry Pi 4, and a look at the current state of play of virtual reality. And it just so happens that in the month that we have a feature on VR, Valve decides to announce that it's time to revisit the *Half-Life* universe in full VR. And my word, *Half Life: Alyx* looks incredible. VR has needed a killer app for a few years, and things were beginning to get pretty desperate, but it appears that Gabe and co. have jumped to the rescue. At the time of going to press, there are a few unknowns, such as how movement will work—whether it'll be teleporting (point where you want to go, and you'll appear there), or some form of joystick-based movement—but if anyone has the answers, Valve hopefully does. Fingers crossed.

I hope you enjoy the issue.

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

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Date: October 8, 2019

THE NEWS

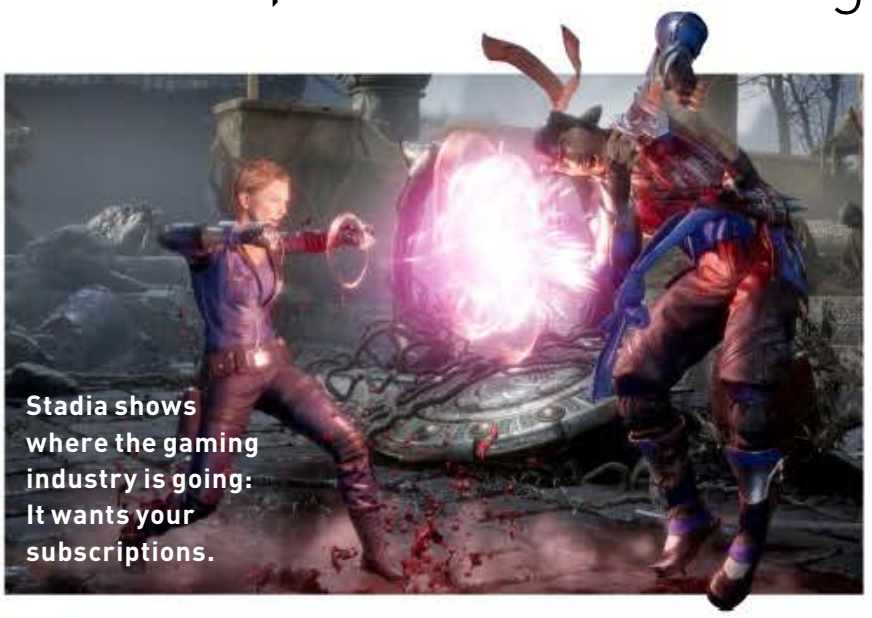
Stream On

Google Stadia is here; others are following fast

GAME STREAMING is going to be big. Google's Stadia has been launched with its Founder's Edition for early adopters (read guinea pigs). For your $129, you get a Stadia controller, a Chromecast Ultra, and a three-month subscription to Stadia Pro, after which it will cost $9.99 a month. Initially destined to have just 12 "carefully selected" games, Google added another 10 just before launch. There are some decent titles, including *Destiny 2, Mortal Kombat 11,* and *Red Dead Redemption 2.* A reasonable start, but Google needs to add more games quickly. Stadia will come in two levels, a subscription-free base level, and Stadia Pro, which unlocks 4K, free games, discounts, and more.

There have been a few teething troubles. Many didn't get access codes they needed, cue much grumbling. More importantly, it seems it can put a strain on the Chromecast Ultra, making it get alarmingly hot, and potentially crashing. Stadia only works with the supplied dongles, so this is something Google should have picked up before shipping. Bandwidth is everything: You need a consistent 10MB/s for 720p, 20MB/s for 1080p, and at least 35MB/s for 4K.

Does it work? Yes. But not terribly well yet. The big issue with game streaming is latency. So far, Stadia has received mixed reviews. There have been complaints of fuzzy images, dropped frames, glitches, and lags. It is also having trouble reaching the promised 4K—*Red Dead Redemption 2* only runs at 1440p, and *Destiny 2* at 1080p. It's not all bad, though, and when it works as advertised, it's impressive, but the Founder's Edition feels more like a beta test than a proper launch at times. It doesn't rival the full gaming PC or console experience, but it is here, and it (mostly) works.



Stadia shows where the gaming industry is going: It wants your subscriptions.

Stadia isn't alone. We have PlayStation Now and Nvidia's GeForce Now already. The PlayStation service is propriety, and limited to 720p, but does have a comprehensive library of over 800 games. It also halved its price recently to $9.99 a month. GeForce Now is a PC-based service with a library of about 80 games, which it can run at up to 1080p, but it only plays games you own. It costs $8 a month.

These will soon be joined by Microsoft's xCloud, currently in a public beta. This enables you to play Xbox games on Android devices (wider hardware support is promised). It has about 50 games. It's not touted as a replacement for consoles, but as an adjunct that enables you to play your games while you aren't in front of your console. None of these services have the potential scope of Stadia.

Google's Stadia is here, and it works, mostly.

Valve is also rumored to be working on a game streaming service. This makes sense, because if streaming takes off, Steam will be hit hard with its "buy a game, play a game forever" model. It certainly has the catalog of games you need, but there are technical hurdles in getting many of the older titles to run.

Amazon is said to be working on a cloud gaming service, too. It doesn't have the games, but it does have massive cloud computing muscle and deep pockets. It has already begun recruiting people for "innovative new uses cases like machine vision and game streaming." The company is expected to go public with its plans next year.

Why such a rush to game streaming? If you can tie customers down to a monthly payment, you can turn small sums into big ones as the years roll by. A whole generation has also grown up inured to paying for things month by month. $10 a month may not sound like much, but if you spend the next 30 years playing video games, that's $3,600.

Game streaming has the potential to change the way we play games. We aren't there yet technically, but the market is heading that way. And it's going to be competitive, with half a dozen of the biggest tech names vying for your custom. To win this fight, you need the magic combination of the top titles, cross-platform support, and the ability to run them fast enough. There is still a lot of work to do—Stadia helps to point the way, but in its current form, it's only a contender, not the winner. **–CL**

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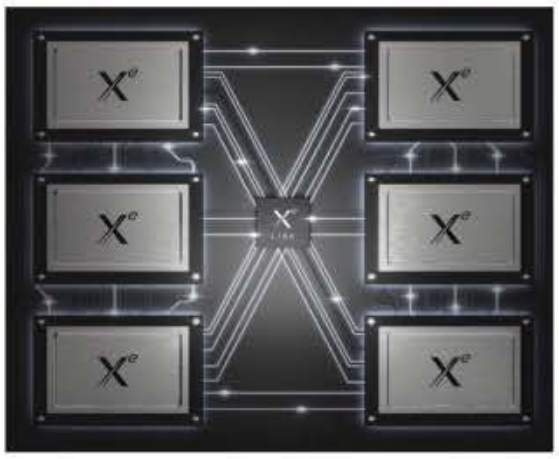

INTEL ENTERS DISCRETE GPU MARKET

THE WORLD OF CONSUMER GPUS has been a contest between AMD and Nvidia for so long, it's hard to remember that the market used to be crowded with contenders. That will change—Intel has been working on its own discrete graphics card tech, the Xe Graphics Architecture, for some time. Its first iteration, code-named Ponte Vecchio, is a 7nm chip (Intel's first). It uses a high-speed Compute Express Link (CXL) and Intel's 3D Foveros system, which enables chips to be built in layers. It has also announced its first card featuring Ponte Vecchio, which Intel claims is an exascale GPU (capable of a billion, billion FLOPs).

Before we get carried away, Intel is aiming its initial efforts at the very top of the market; this is a server card for heavy HPC and AI workloads. And to make good on that exascale promise requires multiple cards working together. There are some mouth-watering high-end technologies at play. The CXL interface requires PCIe 5.0, for example; we've barely got PCIe 4.0 on desktops. Intel has released some baffling material on Xe, but what is clear is that it has been engineered to be highly scalable, and interconnected at all levels.

The consumer version of the Xe Graphics Architecture won't arrive until next year, and will probably be built on a 10nm process. Performance will be in the more realistic teraFLOP department. The Xe family will eventually come in three main brands: the high-end Xe-HPC, Xe-HP for data centers and professional workstations, and Xe-LP for consumers. Intel has made plans for virtually every market segment, right down to laptops and integrated graphics. This is a massive project, in time and money, and it's clear Intel is serious about making a concerted grab for the GPU market. It's about time we had another horse in the race. **–CL**

FIREFOX BUG SCAM

ANOTHER AUTHENTICATION POP-UP EXPLOITATION

SCAMMERS HAVE BEEN EXPLOITING a bug in Firefox that can cause the browser to freeze, even resisting a restart. When you hit a booby-trapped page, the malicious code stops Firefox, and a pop-up appears that claims your Windows Registry key is illegal. You are invited to ring technical support within five minutes, or your system will be disabled. You're put through to a person claiming to be from Microsoft, who tries to get you to pay for a Windows license you don't need. It can get nasty, as you can't close the pop-up. The only way to get out of the loop is to shut down the process in Task Manager. If you have Tab Restore enabled (turned off by default), it reappears next time you start the browser. To clear it, you then need to disconnect from the network or change the preferences. Mozilla has fixed the bug, and by the time you read this, it should be patched as part of build 71, but there is another lock-up bug that remains unfixed two years after it was reported. It's a pity it takes a callous scam to get these vulnerabilities mended. **–CL**

NAVI GOES PROFESSIONAL

Workstations get efficient 7nm graphics

AMD HAS A NEW WORKSTATION graphics card based around its 7nm Navi GPU: the Radeon Pro W5700. It's a workstation version of the consumer RX 5700, and uses the same Navi 10 GPU. AMD has changed its card naming convention, shortening the WX prefix to a plain W, and bringing the numbers into line between the two ranges. The W5700 has 36 compute units, 8GB of GDDR6, and runs at a maximum clock of 1,930MHz. This is faster then the RX 5700, and pushes the 32-bit floating point performance above the RX 5700 XT. It's for graphics work, not AI; AMD is still behind Nvidia here. The W5700 is touted as a replacement for both the Vega-based WX 8200 and Polaris-based WX 7100; it isn't as fast on paper as the former, but it is much more efficient. AMD released benchmarks pitching it against the Nvidia Quadro RTX 4000, where it more than holds its own. The W5700 costs $799, and more Navi workstation cards are expected soon. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

SUSPENDED ANIMATION
A trial to treat trauma can put people into suspended animation for up to two hours, by replacing blood with ice-cold saline.

GLASS STORAGE
Microsoft's Project Silica has stored the movie *Superman* in a pane of glass using 100-plus layers of "voxels."

5G TYRE
Pirelli's Cyber Tire uses sensors and 5G to transmit data on road conditions to nearby cars.

TRAGEDIES

MY PEOPLE TO DIE
Microsoft has stopped development for My People in Win 10. Very few people used it.

PATCH HITS PERFORMANCE
A fix for a bug in Intel's Skylake architecture has taken a couple of percent off its performance; compiler fixes will reduce that.

UBER TO RECORD YOU
As an aid to security, Uber plans to make audio recordings of your journey, initially in Latin America, but destined to come here.

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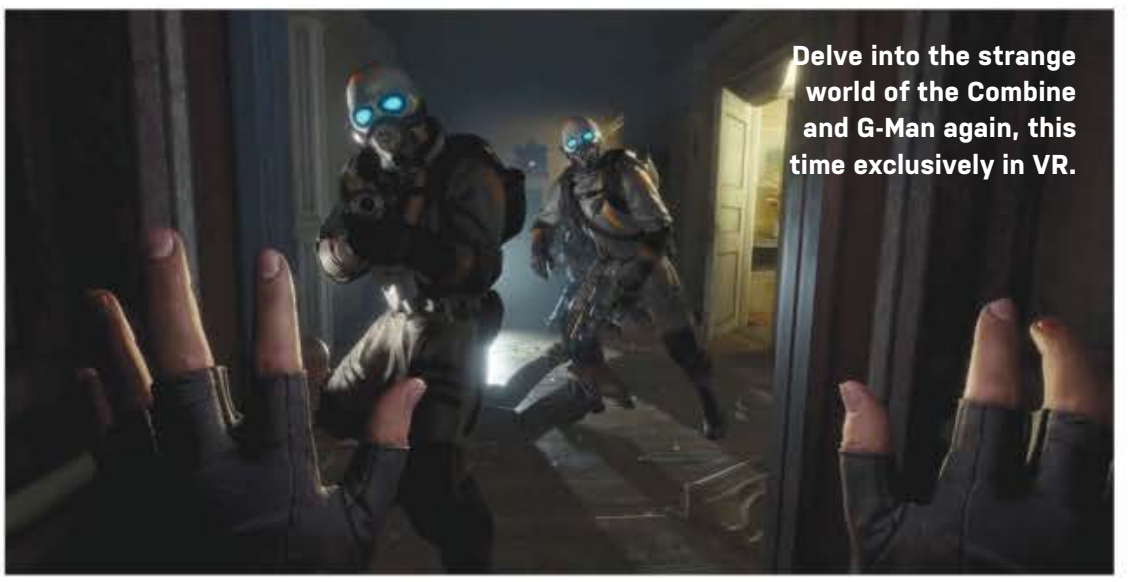
Half-Life Goes VR

VIRTUAL REALITY has been the Next Big Thing for so long it's gone beyond a joke. We look at the state of play in the VR market on page 46, and one conclusion is that VR still needs a game that makes you want to jump on board just to play it—the killer app. Valve may be about to provide such an incentive: a AAA VR exclusive, *Half-Life: Alyx.*

It's set between the first and second main *Half-Life* games, follows the adventures of Alyx Vance, the secondary character from *Half-Life 2,* and promises to be the same mix of tense combat, puzzles, and strong story line. You interact with the world via a pair of disembodied hands, which looks a little strange at first. The Gravity Gun makes an appearance, and so-called Grabbity Gloves enable you to manipulate objects at a distance. The game has been built from the ground up using Valve's Source 2 game engine, the first big title to do so. The release is due in March 2020. It'll set you back $60, or if you spring for a Valve Index headset, it'll come as part of the bundle. However, this high-end tethered system costs a buck short of a $1,000. Ouch.

This has been some time in coming—back in February 2017, the head of Valve, Gabe Newell, said the company was working on three new "full" VR games. We shall see if it's been worth the wait, but the material we've seen so far does look mighty fine. *Half-Life* was the game that made Valve as a company, perhaps this new installment can help make VR, too. All good stuff, but can we also have the final part of the story, please? Episode 3 remains tantalizingly elusive. **–CL**



Delve into the strange world of the Combine and G-Man again, this time exclusively in VR.

©VALVE

Autonomous Car Failure

The official report by the NTSB (National Transportation Safety Board) into the death cased by an autonomous Uber car last year has put the blame on human error and software failure. The safety driver failed to monitor the road ahead, and the car's software failed to recognize that a pedestrian was crossing the street until it was too late. It detected the victim six seconds before the impact, but initially took no action because it was not at a designated pedestrian crossing point, so did not register the person as a hazard. Uber has since upgraded the software and resumed testing. The NTSB has urged federal legislators to review the process of testing autonomous vehicles on public roads. **–CL**

Lasers Hack Smart speaker

Researchers at the University of Michigan and University of Electro-Communications in Tokyo have hacked into a home smart speaker using a laser. Smart speakers use sensitive silicon microphones that respond to light in a similar way to sound, so can be remotely activated by shining a laser at them, and modulating its intensity to mimic the required phrase. The hack, dubbed Light Command, can be made at 300 feet or more with a powerful laser, or up close using a laser pointer. No need to worry unduly; it's a "proof of concept" hack for now, but it does highlight a weakness in such systems. It doesn't matter how the wake-up phrase is delivered, it will work. A simple solution to this method is a shroud to block the laser. **–CL**

MACBOOK PRO IS 16-INCHER

Latest Apple notebook has biggest screen yet

APPLE HAS LAUNCHED the most powerful notebook it has ever made, the MacBook Pro 16, and it's pretty tasty. The 3072x1920 16-inch Retina display is the largest yet, although it's actually only 0.4 inches larger than the Pro 15. The graphics are handled by an AMD Radeon Pro 5000M chipset, and the numbers crunched by an Intel Core i9 or i7 processor. Good modern silicon; Apple has previously been a little behind the curve here. Inside, there's a six-speaker sound system, including two bass units that cancel out each other's vibrations. It's one of the best sound systems you'll find in any laptop.

All this is powered by a 100Wh battery (up from 83Wh in the Pro 15), enough for up to 11 hours of video playback or web browsing. And, of course, it is sleek, albeit slightly thicker than previous designs. There's up to 8TB of solid state storage, and up to 64GB of RAM; the base model has 512GB of storage and 16GB of RAM.

The keyboard uses a new scissor mechanism—the previous "butterfly" design was notoriously fragile. Last year's attempt to fix things using a membrane was the last straw, and it has admitted defeat. The change also means more key travel and a better feel. To counter the thermal throttling that blighted previous models, there's a larger heatsink, increased airflow, and more attention paid to where the air is going.

The MacBook Pro answers most of the criticisms made of the MacBook Pro 15. Better battery, modern silicon, and a keyboard that won't stop working because a piece of dust worked its way under a key. The bigger screen is a minor upgrade—it's all the other changes that make this easily the best MacBook yet. The downsides? It ain't cheap. Prices start at $2,399, but if you click on all the options, you can hit $6,099. **–CL**

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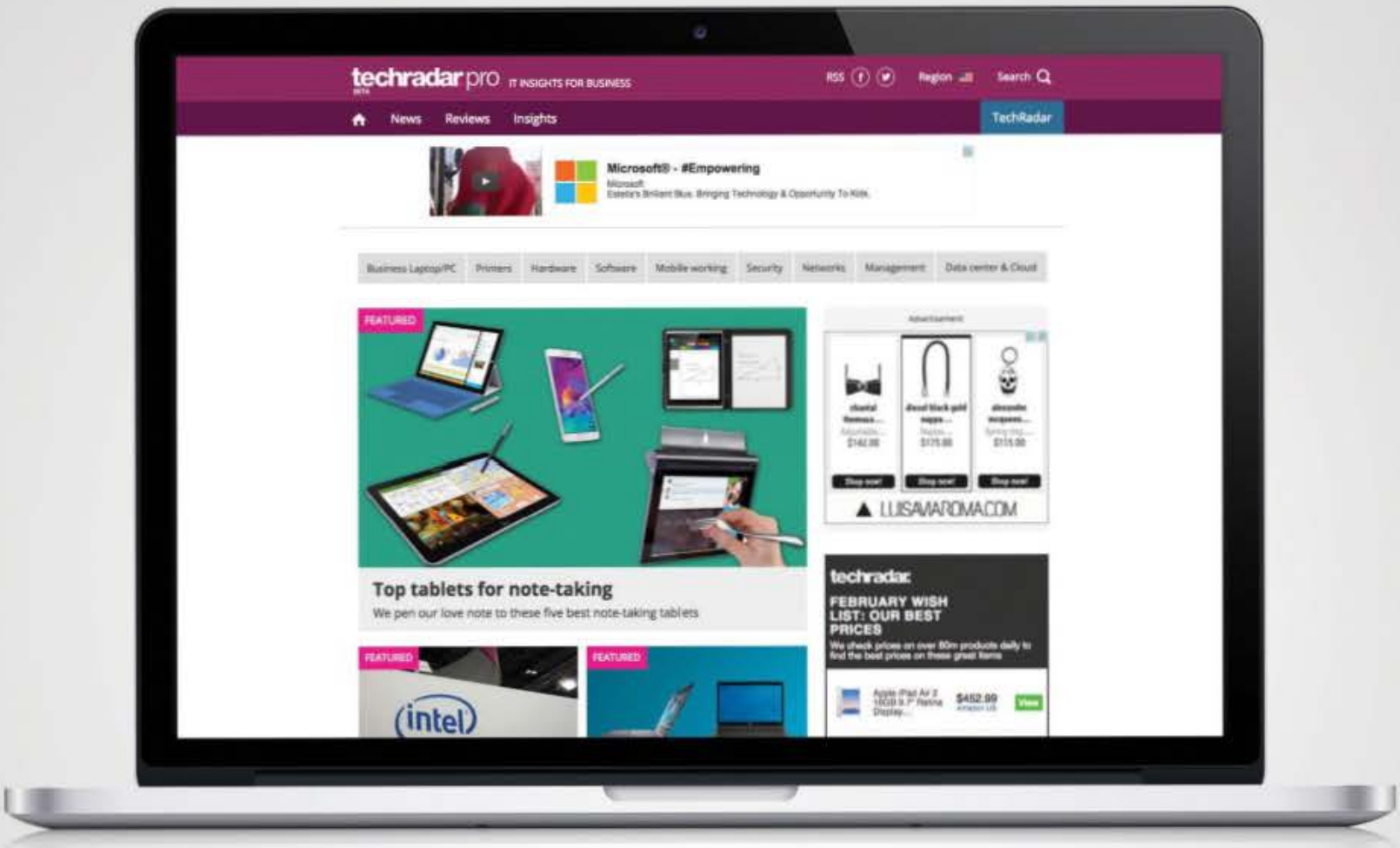

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TECH TALK

What We Can Expect Next from Nvidia

WHAT DOES NVIDIA have planned for its next round of graphics cards? The Turing architecture is coming up on its second birthday, and after the Super refresh, everyone is looking to 7nm and the Ampere architecture. At least, I think it's called Ampere—Nvidia is being tight-lipped, as usual.

To be clear, anyone claiming to have specifications for the RTX 3080 right now is making stuff up. But even if we don't know the exact specs, looking at the underlying tech—TSMC's and Samsung's 7nm process technologies—can provide a good sense of what Nvidia is likely to do.

Nvidia GPUs build on each preceding generation, adding features and improvements. Turing is like Pascal, with new ray-tracing and Tensor hardware, concurrent FP and INT execution, an improved NVENC block for video encoding, and some other tweaks. Pascal is like Maxwell, with tweaks to the architecture and some new features; Pascal also marked a transition from 28nm lithography to 16nm FinFET. Maxwell built on two generations of Kepler GPUs, with better memory compression and some VR-specific features that didn't catch on.

This next transition is going to be the most like the Maxwell to Pascal move, because it's not just about tuning the architecture. The next GeForce series will shrink the process from 12nm to 7nm, paving the way for big improvements. I also expect Nvidia to be less ambitious on pricing, as the RTX 20-series didn't sell as many units as anticipated. The lack of interest from cryptocurrency miners probably had a lot to do with that.

Nvidia isn't likely to do a straight die shrink; instead, it will pack more features and hardware into Ampere GPUs: more RT cores for ray tracing, more CUDA cores for general graphics, and more Tensor cores for machine learning. There will also probably be new tech to improve performance, as Nvidia does that every generation—stuff like variable rate shading.

> Nvidia GPUs build on each preceding generation, adding features and improvements.

Looking to AMD's 7nm parts gives a good idea of how the 7nm process scales. The Vega 20 in the Radeon VII is about 30 percent smaller than Vega 10, while packing in 6 percent more transistors. Even better, the Navi 10 GPU is almost half as large as Vega 10, and the 5700 XT easily outperforms the RX Vega 64, while using 225W instead of 295W. Some of that is architecture, but lots comes from TSMC's 7nm lithography.

Nvidia can already beat AMD's RX 5700 XT, and its Ampere RTX 3080 GPUs will be even faster. It's easy to imagine Nvidia putting 20–25 percent more cores in each level of GPU hardware. The 7nm process should allow Nvidia to clock those cores 20–25 percent higher, too, so Nvidia could have GPUs consistently running at over 2.0GHz. Even with the added cores and features, die sizes should be smaller than Turing equivalents.

We could be looking at a generational improvement in performance of 40-50 percent or more for RTX 3080, with a chip that's still 15 percent smaller than the RTX 2080. What's more, we might not have to wait too long.

The RTX 3080 will likely be 7nm and double down on ray tracing, as used in Atomic Heart.

TSMC has been making 7nm chips since 2018, when the Apple A12 launched. AMD started selling 7nm in late 2018, and has been selling lots of 7nm CPUs and GPUs since July 2019. The time is ripe for Nvidia to launch its first 7nm parts, and past experience suggests that spring 2020 would be ideal.

If you still have a GTX 10-series or similar, or even a GTX 900, you may finally find a reason to upgrade. And wouldn't it be perfect if Nvidia launched RTX 30-series parts, with far better ray-tracing performance, in time for *Cyberpunk 2077?* Maybe we'll have to wait for *Vampire: Bloodlines 2,* but *Cyberpunk* is the bigger target.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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Alex Campbell

OPEN SOURCE

Signal to Move Away from Phone Numbers

SIGNAL PRIVATE MESSENGER, the gold standard for open-source private messaging, is to move away from phone numbers as the primary user ID. This is great news, and may help the app reach more users. At the very least, it will be a boon to privacy.

For as long as I've been writing about tech, I've preferred services and software that help protect privacy. I switched to using Signal as my default mobile messaging app years ago. Since then, Signal has gotten features such as Giphy integration and video calls. But one thing has always irked me: The use of a phone number as a user ID.

For all its accolades, Signal has been criticized for tying a user to a phone number. For users who might want a new number (to avoid calls from a persistent ex, for example), keeping in touch with Signal contacts meant setting up new conversations, security numbers, and a lot of headache. More importantly, talking to someone over Signal required giving out your phone number.

For friends and family, this is clearly not that big a deal. But what if you want to talk with someone you meet at a conference or over Twitter? You might not be comfortable giving up your private number to such an individual. Some other means of establishing identity would be clearly preferable.

The Signal developers have heard calls for this type of feature, and will be releasing it in an upcoming version of the Android client. The 4.50 release gives each user a universally unique identifier (UUID) that will act as the user ID.

While the consequences are largely (as Signal puts it) "behind-the-scenes," the implication is that users may be able to offer up their UUID online without worrying about revealing phone numbers.

> You might not be comfortable giving up your private number to some individuals.

There are other enhancements, too. The 4.50 release will offer up insights to the user, showing what percentage of recent messages were encrypted versus served over unsecured SMS. The analysis will be computed by the device, requiring no communication with Signal servers. For users like me, who use Signal as their primary messaging app, this can be a valuable tool to see how "secure" their conversations are at a glance. Such privacy auditing tools can be useful for those with more stringent privacy requirements.

Truth be told, the messaging landscape is a mess. Apple users have iMessage, which enables encrypted communication, but only with other Apple devices. (Android users famously show up in green chat bubbles.) SMS and MMS are antiquated and insecure. Other platforms, such as Facebook Messenger, WhatsApp, and others, compete with Signal in the third-party messaging space. (Note that WhatsApp uses a version of the Signal protocol under the hood.) The upcoming Rich Communication Services (RCS) standard is being developed by carriers to modernize SMS and MMS to create something more like Google's now defunct Allo. Currently, Google's Messages app is RCS-capable, but the standard isn't end-to-end encrypted (E2EE) like Signal and iMessage are by default. And if Signal did add support for RCS, it would serve as an unencrypted fallback, much like how Signal handles SMS and MMS.

The heterogeneity of messaging standards makes secure chats a pain. Either you use a system everyone else does, even though you don't prefer it (such as iMessage or WhatsApp), or you have to convince your contacts to use another (such as Signal). While this barrier may persist for some time, allowing people to use Signal without relying on a phone number could be a boon for those who wish to use it on laptops or other devices without the need to tie it to a phone.

Signal is a secure open-source messaging app.

Alex Campbell is a Linux geek who enjoys learning about computer security.

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THE LIST

CONSOLE EXCLUSIVES WE WANT ON PC

POKEMON There are emulators, but an official PC game would be amazing. Imagine the VR possibilities!

CRACKDOWN 2 This Xbox 360 classic is still a really enjoyable urban sandbox to fling cars around in.

FABLE II Other *Fable* games have made it to PC, but the superb second iteration is stuck on Xbox 360.

BREATH OF THE WILD This Switch launch title might be the definitive *Zelda* experience—beautiful.

MARVEL'S SPIDER-MAN Sony has been killing it with PlayStation exclusives, and this is no different.

SUPER MARIO GALAXY The best 3D Mario game ever. We'll accept no criticism on this view.

BLOODBORNE *Dark Souls* fans are irate that From Software's faster, bloodier title is a PS4 exclusive.

HORIZON: ZERO DAWN A PlayStation title with a gorgeous open world and likeable characters.

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HEAD TO

BY **CHRISTIAN GUYTON**

Ryzen 3 3200G vs. Core i3-9100 vs. Athlon 3000G

This month, we're turning our heads to accelerated processing units. AMD is killing it at the moment on the integrated graphics front, although Intel's APUs—such as the Core i3-9100—are still top-notch products. If you're looking for a processor to power a budget build, there are plenty of options on the market right now. The Intel versus AMD debate may rage until the end of time, but AMD has given its budget Ryzen 3 3200G APU an extra competitor in the frighteningly cheap Athlon 3000G. Can this affordable underdog take home the crown?

ROUND 1

Value

This is tough. In terms of baseline pricing, the Athlon 3000G should win this round; it's $50, for crying out loud. There's no buying integrated graphics processors with that kind of money, other than the old Celeron and Pentium APUs from Intel that aren't supported on current-gen mobos. The 3000G does sit beneath AMD's other APUs in terms of processing power and features, though. The Intel Core i3-9100 offers a maximum of 16 PCIe lanes and 50 percent more cache memory, while the Ryzen 3 3200G has the fastest memory support: 2,933MHz as opposed to the 9100's 2,400MHz and the 3000G's 2,667MHz.

All three come with an air cooler unit, although Intel's included coolers aren't that impressive. The AMD chips come with the excellent Wraith coolers, which are a good addition to improve the value. The i3-9100 is the most expensive chip by far, costing $165 at the time of writing; more than triple the price of the Athlon 3000G. Meanwhile, the 3200G costs an even $100, which is a perfectly reasonable amount to spend on an APU, but at double the price, it doesn't double the baseline performance of the Athlon, so we're giving the win here to the 3000G.

Winner: Athlon 3000G

ROUND 2

Performance

Shockingly, the super-budget Athlon doesn't win this round. Granted, it's the only chip here with multithreading, bringing its thread count to four; tied with the other two, despite only having two cores. It can't quite match the higher frequencies and superior integrated graphics of the other two. The i3-9100 does well—in CPU-bound tests it outpaces the Ryzen 3 3200G by a small margin (less than 10 percent). However, the 3200G's integrated graphics are better suited to low-end gaming than the i3-9100. It's a case of Radeon Vega 8 against Intel UHD 630, and AMD has a slight edge when rendering graphics in real time.

Neither chip is going to perform outstandingly without a discrete GPU, but the 3200G can carry most games in 720p and even some at 1080p. In our recent budget build, we saw the 3200G play *Rise of the Tomb Raider* at 1080p ultra, with a frame rate almost triple that of the i3-9100. There's no contest in terms of graphical power; the Intel chip is a bit older than the Ryzen, too, utilizing the same integrated graphics as the older i3-8100. So, we lean toward AMD, but once desktop models of Intel CPUs featuring the Iris Plus graphics arrive, our tune may change.

Winner: Ryzen 3 3200G

ROUND 3

Efficiency

APUs tend to have broadly comparable power consumption, with the graphics demanding a bit more juice than conventional CPUs. The Ryzen 3 3200G and Core i3-9100 are both rated for a TDP of 65W, the same as more powerful chips without integrated graphics, such as the Ryzen 5 3600. But Intel and AMD calculate TDP differently, so without getting too deep into the math, the Ryzen chip likely uses slightly less power. The Athlon 3000G, however, has a far lower default TDP of 35W.

Looking at clock speeds, the Ryzen and Core both exceed the Athlon, but when comparing base clocks against TDP, the 3000G comes out on top. Core processors still use less power than many other components (such as GPUs), and overclocking means that power consumption in APUs is potentially variable. None of these chips have brilliant overclocking potential anyway, so the winner here is the 3000G. Its Vega 3 graphics can give Intel's UHD 630 a run for its money, and utilizing SMT means it packs the same number of threads as the other chips without overburdening your power consumption. If you're looking to build a low-power system, this is one of the best APUs around.

Winner: Athlon 3000G

HEAD

From left to right:

The 3200G is currently the cheapest third-gen Ryzen chip.

Intel's Core i3-9100 is a more expensive but speedier APU.

This is AMD's newest, shiniest Athlon chip yet.

ROUND 4

Overclocking

AMD's been having a hard time with overclocking. The Zen 2 Ryzen CPUs (3600 and up) have had serious issues with overclocking headroom, rarely able to hit their advertised boost clocks across multiple cores. The 3200G uses the 12nm Zen+ architecture, which is a bit more stable, but still isn't able to hit any particularly dizzying heights. The Athlon 3000G comes unlocked, using the even older 14nm Zen architecture, and is capable of boosting its 3.5GHz base clock up to 3.9GHz. That might not sound like much, but it's the same increase as the 3200G's theoretical base to boost clock.

Intel has the edge here, though, with the reliable Coffee Lake architecture capable of handling an overclock of up to 600MHz more than its base clock of 3.6GHz. It can do this easily in single cores, or a little less reliably across all cores. It still comfortably outperforms the other two in manual overclocking. With auto overclocking, the waters are muddied. AMD's Ryzen Master software gives the 3200G a slight edge, and does tend to improve performance by a reasonable amount. Overall, though, we'd have to give it to the Intel chip; the potential headroom for overclocking is simply greater.

Winner: Core i3-9100

ROUND 5

Flexibility

All three chips can form a solid foundation for an upgradable custom system, and all are relatively new (the oldest, the Core i9-9100, is less than a year old). Longevity is to be expected from CPUs in this day and age, and each chip here presents that. Quad-core (or quad-thread, in the case of the 3000G) is enough to handle any ordinary work on a regular basis, and there's the potential to upgrade to a discrete GPU for more graphical oomf. But which of these chips best supports future upgrades and expansions?

The i3-9100 might not be the obvious answer; it has the slowest memory support, and its higher price makes it look more like a budget upgrade piece than an upgradable baseline. But it has more cache memory, a higher boost clock, and most importantly, it has more available PCI Express lanes, thanks to Intel graphics connecting differently. This leaves more support for upgrades; expansion cards, SSDs, whatever else you might want to add to a evolving build. There are a lot of factors at play here. If the AMD chips had support for PCIe 4.0—currently an AMD-exclusive feature of Zen 2—we might have changed our minds, but as it stands, we're giving the win to Intel.

Winner: Core i3-9100

And the Winner Is...

We're calling this one a tie. That's between AMD's Athlon 3000G and the Intel Core i3-9100; the Ryzen 3 3200G is a good low-end gaming APU, but it lacks the raw CPU performance of the i3-9100 or the exceptionally modest pricing of the 3000G. Just so we're clear, the i3-9100 is the better processor, but it sits almost in a different bracket to the Athlon 3000G. We included an Intel chip for variety, but it overpowers both of these AMD APUs; a more realistic comparison would be the excellent Ryzen 5 3400G.

The Athlon 3000G sits at the ultra-budget end, and we love it for that. It's almost hilariously affordable, and we can't wait to build with it. The low price makes it a great chip for budget systems, and we might even go so far as to recommend it for more esoteric purposes, such as CPU-bound cryptocurrency mining. It's worth noting that while the 3200G is the loser here, it's not a bad chip. All three of these are worthy APUs in their own rights; the real deciding factor for any prospective buyer should actually just be the price.

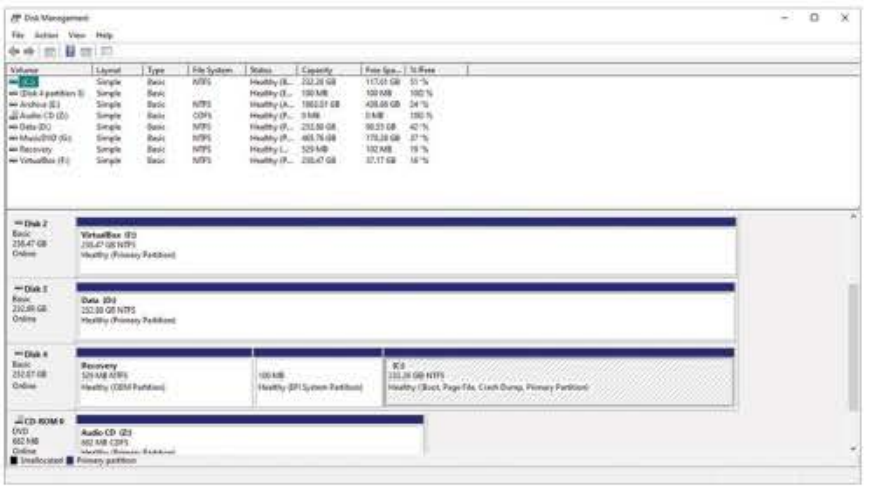
DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> OpenVPN Confusion
> Poor Performance
> AMD Mobo Woes

Best Drive Layout

In the early days of computing, it was often recommended that the OS live on a separate disk, or at least a separate partition. In this new age of solid-state disks, what do you recommend? Cost and space for multiple disks isn't an issue. **–Daniel Swanson**



We've split Windows and our apps on to a different drive from our data, but you can use partitions, too.

THE DOCTOR RESPONDS: Keeping the OS (and apps) separate from your data is pretty much a matter of personal convenience—the key thing is that you don't get lulled into a false sense of security and forget to keep everything backed up separately. The Doc has long split his data from the OS and apps—originally through partitioning, but now on separate drives. That's largely down to the smaller size of SSDs compared to regular HDDs, coupled with a growing accumulation of drives over successive rebuilds.

Long story short: If you want to follow the Doc's layout, start with a single, dedicated SSD (or NVMe) drive for Windows and your apps—typically 256GB, but as little as 128GB if your app demands aren't too great. In the past, we'd have dumped all our data on a traditional spinning HDD, but if you have a spare SSD, keep your key data files on here for faster access, leaving the regular HDD for archived files that you no longer need to access regularly.

This ensures that if your OS goes down, you can restore it without touching your data; similarly, if your data drive dies, you can restore that without having to reload the OS from scratch. Of course, none of this replaces the need to back up everything independently. The Doc uses Macrium Reflect Free to back up his OS/apps alternately to his internal HDD and a QNAP NAS, while both File History and a Nextcloud server act to back up data (including previous versions of files) to the QNAP NAS. For good measure, the Doc now also backs up key OneDrive folders via the QNAP's Hybrid Backup Sync tool, making use of its encryption tools to provide an extra layer of security.

Server Solutions

I plan to rebuild an MSI 970/AMD CPU as a Linux machine to run various servers: Nextcloud, a small website, and possibly a Plex server. I came across the Holiday 2018 article on creating secret and secure web servers, which requires a Linux PC running OpenVPN. This suggested it should be on an OpenSUSE Leap 42.3 distro. Does it have to be? Also, what if you run OpenVPN on a router—does that change the process? I have a T-Mobile TM-AC1900 (a rebranded Asus RT-AC68U) that's firmware-locked. I can run the VPN on my mobile devices just fine, and I have set up a TV/DVR stream using NextPVR on my Windows machine that can only be reached through the VPN. I guess this is different from the Linux-based OpenVPN server by a magnitude of, well, a lot.

The idea is to make the Nextcloud instance hidden and secure. Any tips would be appreciated. Thanks!

–Anthony Prevo

THE DOCTOR RESPONDS: The answer could be a lot simpler than you think. As an aside, you can run OpenVPN on most Linux distros; the author simply mentions OpenSUSE because it's the one he used to write the tutorial. However, if you've already got OpenVPN up and running on your router, this step may be unnecessary. All the key functionality you require should be achievable using your router's own OpenVPN server.

Let's assume you've not changed two key OpenVPN Server advanced settings on your router: The interface type is set to TUN, and the VPN

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↘ submit your questions to: doctor@maximumpc.com

network and subnet is set to 10.8.0.0/255.255.255.0, while "Push LAN to clients" is set to Yes. Also make sure "Respond to DNS" and "Advertise DNS to clients" are set to Yes to help performance. One final tweak: Go to the "Route" tab under "Advanced → LAN," and set "Enable static routes" to Yes.

Note: This step requires your TM-AC1900 to be running firmware that supports OpenVPN—Asus has been aggressive in replacing modified firmware with the stock TM-AC1900 firmware that doesn't support these features. If shopping for a bargain, be sure you're buying a genuine Asus RT-AC68U, not the T-Mobile version.

Once the server and clients are set up, you need to set up your Linux server with Nextcloud, leaving any remote access options disabled, so it's only accessible from inside your local network. When you install Nextcloud on your devices, point it toward the local instance; for example, https://nextcloudpi.local/ if you followed our guide to NextCloudPi in the November 2019 issue. Once you've got this working internally, try dialing in remotely using your OpenVPN client—you should find Nextcloud works as if you were on your local network, albeit a bit slower, to allow for the secure remote connection.

Vulkan Drivers

With the recent drop in Nvidia 2070 prices, I took the opportunity to upgrade my Radeon 5950 to a ROG-STRIX-RTX 2070-08G on my MSI Z87-GD65 gaming setup, with an i7-4770K CPU, and 32GB of 2,400MHz RAM. My frame rates have been low while using Nvidia's Vulkan driver—*Doom* had frame rates in the 40s, but when I switched to the OpenGL driver, they were in line with my expectations: as high as 200, and smooth play. Many games don't have the option to choose OpenGL; do you have any suggestions?

–Lonny Beal

Check your security software isn't blocking access to your webcam.

THE DOC RESPONDS: You're not alone in your complaints, and you'll find all kinds of theories for why this may be happening. It appears to affect Nvidia cards more than AMD ones, which some put down to the fact that AMD cards are optimized for low-level APIs, such as Vulkan, while Nvidia still favors high-level ones.

Brad Wardell of Stardock has an additional explanation: complexity (see https://ubm.io/2OmAVQ9). While Vulkan and its competitor, DirectX 12, offer such improvements as GPU multitasking, they offload the responsibility for certain aspects of those APIs—from memory to multiple threads—to the app developer. So, you're relying heavily on app developers to get to grips with Vulkan drivers in a different way from how they had to with OpenGL. And when it comes to those older games written for OpenGL and DirectX 11, some will end up performing better with those drivers than the newer ones.

Webcam Compatibility

A Google search suggests that the Microsoft Lifecam HD-3000 does not work with Windows 10 (32 or 64-bit). Evidently also the Logitech C920. Were any of the webcams reviewed in the October 2019 issue tested successfully with Windows 10 64-bit?

–Robert Rue

THE DOC RESPONDS: You can relax, Rob: We base our recommendations on testing, not online clickbait. The C920 is reported as Windows 10-compatible on the Logitech website—we'd have been surprised if it hadn't been, given Logitech's much older C720 webcam works perfectly on our Windows 10 rig.

The one webcam where you might have had a tiny point might have been the Lifecam HD-3000—a trip to Microsoft's website suggests it only works up to Win 7, but that's because the download is for Microsoft's own defunct webcam software. Lifecam drivers are installed automatically with Win 10—and if you don't believe us, take a trip to www.catalog.update.microsoft.com where a search for "lifecam hd-3000" reveals both 32-bit and 64-bit Windows 10 drivers do exist. While there's no software to download, you'll find the Lifecam works happily with existing software, including Skype and Microsoft's own Camera app.

Where people have had problems with Windows 10 in the past, these problems have been fixed. We remember the Win 10 Anniversary Update dropped support for certain types of compressed streams that caused our Logitech C720 to fall over in certain apps, but Microsoft issued a fix. One place webcam users often trip up is in ensuring both Windows and their security app have given permission for the camera to function—in Windows, head to "Start → Settings → Privacy → Camera" to verify you've granted apps permission to access installed cameras. Security tools should have similar features—in Bitdefender, for example, navigate to "Privacy → Webcam access."

QSV and Dual CPUs

The video management software I will be using for a surveillance server has support for a GPU, but there are some requirements: The CPU, mobo, and GPU must all support QSV. I wanted to build a dual-Xeon processor server with hardware RAID 60 support (24 drives—three legs of eight drives each) for this video surveillance (under 128 CCTV cameras), but it doesn't look like QuickSync works with dual processors. Is this true? **–Jim DiPasquale**

THE DOC RESPONDS: Sadly, you're correct: Intel's Xeon Scalable processor family doesn't support QuickSync Video, largely because none of them currently have integrated graphics, instead relying on third-party GPUs. It leaves you having to make a hard choice: If a dual-processor setup is vital to meet your hardware needs, you'll need to switch to a software solution that supports GPUs and hardware encoding on discrete cards, like those offered by AMD and Nvidia instead.

However, if you think you might be able to get by with just a single multicore processor, Intel's Xeon E-2100 series is where you should focus your attention. Virtually all models in this range come with integrated graphics (look for the tell-tale G at the end of the model name), all of which have QuickSync support. The current top-line model—the E-2288G—offers eight cores, 16 threads, and 3.7GHz (5GHz turbo) processor speed, plus support for up to 128GB RAM. Onboard graphics is handled by the Intel UHD Graphics P630 chip. Just make sure you pair it with a motherboard using the C246 chipset, which supports embedded graphics and thus QSV.

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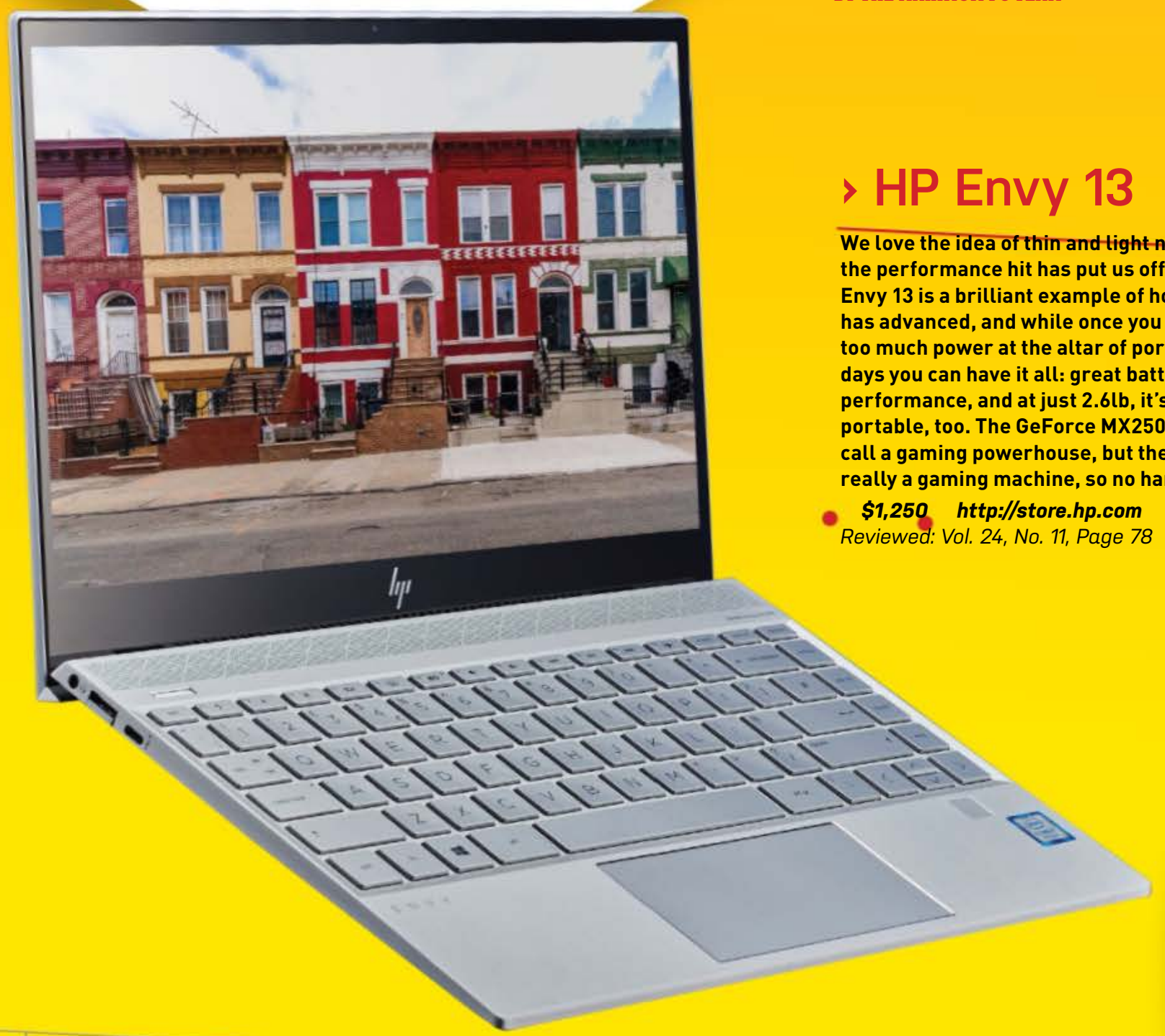
GEAR OF THE YEAR

OVER THE NEXT 10 PAGES, you'll find the best gear to have been released this year. The hardware, systems, and components that stand out as the best options around. If you're looking to treat yourself, this makes for a great wishlist of where to drop your cash. Or, if you've already bought something that we've covered, congratulations—you have great taste.

The big news of 2019 was the release of AMD's Zen 2 architecture, as found in the Ryzen 3000 series of CPUs, and with it came support for PCIe 4.0, which saw impressive bandwidths in SSDs in particular. There's been plenty of great motherboards for these new chips, too, making it a great time for anyone looking to upgrade their system with a whole new powerful base with lots of cores and threads.

A quick look through the list will reveal that Intel's desktop CPUs haven't made the cut, and the same goes for Nvidia's high-end GPUs, which failed to make the list due to their high price and lack of a killer app for real-time ray tracing. Still, there have been some great GPUs at the lower end of the stack, and you'll find our favorites here.

BY THE MAXIMUM PC TEAM



› HP Envy 13

We love the idea of thin and light notebooks, but the performance hit has put us off. Until now. The Envy 13 is a brilliant example of how far the genre has advanced, and while once you were sacrificing too much power at the altar of portability, these days you can have it all: great battery life, strong performance, and at just 2.6lb, it's seriously portable, too. The GeForce MX250 isn't what you'd call a gaming powerhouse, but then this isn't really a gaming machine, so no harm done.

$1,250 ***http://store.hp.com***

Reviewed: Vol. 24, No. 11, Page 78

› Raspberry Pi 4 Model B 4GB

The latest iteration of the tiniest budget PC continues to impress us with its improved performance—now boasting a proper internal infrastructure that gives you plenty of bandwidth for gigabit networking and USB 3 interfaces, as well as support for dual displays at up to 4K. This 4GB model is great for use as a desktop PC, although cheaper 1GB and 2GB models are also available. Check out this month's feature on page 34 for plenty of Raspberry Pi 4 projects.

$55 ● ***www.raspberrypi.org***

Reviewed: Vol. 24, No. 9, Page 79

› Acer Predator Helios 700

So, you want to play the latest AAA games, but you also need the machine in question to be portable? You'll want to put the Helios 700 on your wishlist, then. It's not cheap, and it's not exactly subtle, either, but it does pack some serious hardware into its clever chassis (the keyboard slides down for extra cooling): GeForce RTX 2080, Core i9-9980HK, 144Hz 1080p display, and 64GB of RAM. This is a beast of a machine, in every sense of the word.

$3,499 ● ***www.acer.com***

Reviewed: Vol. 24, No. 12, Page 78

› Maingear Vybe

Proving that high-end gear doesn't have to cost the earth, the Maingear Vybe family starts at just $699, but nets you a quality system whatever you select. The machine we got in for review sits at the top of the range (and has since been upgraded from an RTX 2080 to an RTX 2080 Super), and performed brilliantly, as to be expected. The sober NZXT case styling combined with classy RGB lighting made for a tasteful system, that when backed up with the generous warranty, made for the near-perfect prebuild.

$2,499 ***www.maingear.com***

Reviewed: Vol. 24, No. 6, Page 78

› Falcon Northwest Talon 20th Anniversary

That Falcon Northwest has been making quality machines long enough to produce a 20th anniversary model is testament to the company's capabilities. Here's a firm that knows what buyers want, and knows what it's doing. Anyone looking for a beautifully crafted machine, brimming with the latest hardware, will be delighted with this anniversary build, which in our case came with dual RTX 2080 Supers, a Ryzen 9 3900X, and RAIDed SSDs. The fact that it also comes with such slick aesthetics is the cherry on top.

$5,316 ***www.falcon-nw.com***

Reviewed: Vol. 24, No. 13, Page 76

› Corsair One Pro i180

Convention dictates that those looking for serious performance need to make do with boring-looking workstations. And that such a system will be massive. Not so the Corsair One Pro i180. Brimming with the latest hardware, this machine not only has the performance to turn heads, but it has the looks as well. Its diminutive frame, smart styling, and ingenious cooling make for one of the most appealing systems we've ever had in the Maximum PC office. Expensive, but oh so worth it.

$6,799 ***www.corsair.com***

Reviewed: Vol. 24, No. 7, Page 76

› Acer ConceptD 500

Corsair isn't having the workstation redesign party all to itself, because Acer has turned up fashionably late with its own take on proceedings in the form of the ConceptD 500. Boasting slightly more sober styling and a more traditional form factor, this workstation still manages to impress both in terms of performance and looks. We would have preferred some beefier fans inside the case, but the rest of the components are up to snuff, and overall we like where the workstation market is heading.

$4,000 ***www.acer.com***

Reviewed: Vol. 24, No. 12, Page 76

› AMD Ryzen 7 3700X

If your funds don't quite stretch to the top of AMD's Zen 2 stack, the Ryzen 7 3700X is where the sensible money sits. Your $330 nets you an eight-core, 16-thread processor that can chew through the majority of tasks easily, and thanks to the support for PCIe Gen 4, you won't be waiting around for your data either. Overclocking headroom is admittedly a little weak, and Intel still gets the nod for dedicated gaming, but don't let that detract from a phenomenal package.

$329 ● ***www.amd.com***

Reviewed: Vol. 24, No. 10, Page 74

› AMD Ryzen 9 3900X

The 3900X may have just been supplanted by the 3950X at the top of the stack, but it remains our go-to chip for anyone seeking phenomenal performance at a reasonable price. This 12-core, 24-thread CPU has more than enough processing power for serious work, and manages to challenge enthusiast-class chips in the process. Throw in support for PCIe Gen 4 (and those tasty SSDs, in particular), and the fact that it comes with a decent air cooler, and this is a great overall package.

$500 ● ***www.amd.com***

Reviewed: Vol. 24, No. 9, Page 72

› ASRock X570 Taichi

Regardless of whether the steampunk styling is to your taste, the X570 Taichi makes for a great starting point for any prospective Ryzen 3000 build. Strong performance comes as standard, and thanks to the swathes of metal covering the lower half of the board, this is a sturdy base as well. Power draw is a tad higher than similar X470 offerings, but M.2 throughput makes up for that, while the connection-rich I/O panel, complete with integrated shield, makes for a versatile basis for any machine.

$300 ● ***www.asrock.com***

Reviewed: Vol. 24, No. 10, Page 82

› Zotac Gaming GeForce RTX 2060 6GB

Nvidia's RTX graphics cards started rolling out at the end of last year, and while they've all seen updates with the Super renditions, only the original RTX 2060 really stands out as a must-buy graphics card. This is mainly due to the fact that its price tag isn't absurd. While you won't be playing ray-traced titles at the higher resolutions, it'll trace those rays at 1080p, and normal games run smoothly at 1440p.

$333 ***www.zotac.com***

Reviewed: Vol. 24, No. 4, Page 80

› EVGA GeForce GTX 1660 Super SC Ultra

Nvidia's decision to release budget-focused cards based on Turing, but without the real-time ray-tracing support, may have been an odd pitch, but it paid off in terms of value for money. Releasing "Super" renditions was also something of an odd angle, but again, it paid off, resulting in near-1660 Ti levels of performance, for less money. The 1660 Super will rock 1080p gaming at the highest settings, and have a good try at 1440p if you ease back on the settings.

$230 ***www.evga.com***

Reviewed: Vol. 24, No. 13, Page 80

› Asus ROG Crosshair VIII Formula

Asus went back to the drawing board for the Crosshair VIII Formula, and returned with a motherboard that rethinks how cooling works for Ryzen 3000. Anyone wanting to really push the top-tier Zen 2 chips need look no further than this behemoth of black metal and mirrors. You'll want to be a bit of a pro with the old water cooling, but if you are, this will pay richly—we liked it so much that we used it in our big build last issue. The only obvious downside is the price.

$600 ***www.asus.com***

Reviewed: Vol. 24, No. 12, Page 84

› Phanteks Eclipse P600S

There's a lot of subjectivity when it comes to cases—if you don't like the look of it, it doesn't matter how good the airflow is or how easy it is to build inside—even so, when we looked at this case earlier this year, we honestly couldn't find any serious negatives against it. The layout is fantastic, the build quality and material choices impeccable, and all for a lower price than you'd usually pay for such a premium case.

$145 ***www.phanteks.com***

Reviewed: Vol. 24, No. 4, Page 84

› NZXT H510 Elite

NZXT has produced some incredible cases over the years, and the H510 Elite joins those ranks, thanks to its clean lines and combination of smoked glass and white base. This case boasts some brilliant cable management, impressive lighting capabilities, and thanks to that spacious bottom compartment, can be the foundation of a brilliant build. There is somewhat limited space for larger radiators, and it is a bit on the pricey side, but it's still an incredible option.

$170 ***www.nzxt.com***

Reviewed: Vol. 24, No. 10, Page 88

› Noctua NH-U12A

If you want serious cooling, you go water (either custom loop or an all-in-one), but if you want to stick with air, Noctua is often the answer. Its beige-themed range of CPU coolers may not look like much, but the cooling on offer is always impressive. The NH-U12A managed to keep our test Ryzen 5 2600X at a steady 60 C under full load, and idling at 30 C, while being whisper quiet. It can be tricky to install on some mobos, but well worth the investment.

$100 ***www.noctua.at***

Reviewed: Vol. 24, No. 6, Page 87

› Zadak Spark RGB 16GB DDR4 4,133MHz

High-performance RAM is tricky to recommend, simply because while there are some specific applications where you can see the performance benefits, for most day-to-day uses, you'll be hard pushed to justify dropping so much cash on it. That said, this high-speed Zadak kit managed to wow us convincingly with its high bandwidth and low latency. It also happens to be a good-looking pair of sticks, which could swing your decision if you have a windowed case to show off your investment.

$280 ***www.zadak.biz***

Reviewed: Vol. 24, No. 11, Page 86

› Corsair MP600 1TB

One of the big stories with the release of the Ryzen 3000 series chips was support for PCI Express 4.0, and the Corsair MP600 was one of the first drives to hit the scene. It just so happens to be one of the best options as well, with its snazzy passive cooling and its frankly ridiculous transfer rates—particularly when it comes to 4.9GB/s sequential read and 4.2GB/s write speeds. If you want next-gen drive performance, you've found it.

$190 ***www.corsair.com***

Reviewed: Vol. 24, No. 10, Page 84

› Acer Predator X27

We've looked at plenty of screens in the last 12 months, but apart from one exception (see page 84), none of them have managed to surpass the screen we looked at back in the January issue. The Predator X27 offers up the best HDR implementation we've seen so far, thanks to its dynamic 384-zone local dimming. This is quite a bit of cash for a 27-inch screen, even if it is a 4K, G-Sync model, with a 144Hz refresh rate. Still, if you want the best, you've got to pay.

$1,899 ***www.acer.com***

Reviewed: Vol. 24, No. 1, Page 82

› Audio-Technica ATH-M50xBT

Enjoying a proper studio-grade soundstage from Bluetooth headphones is rarer than you might think, especially if you're looking for sound canceling at the same time. The ATH-M50xBT headphones check that specific box beautifully, though, offering up plenty of bass, but with crystal clear midtones and highs, in a package that folds up neatly when you're out and about. Build quality is impeccable, they're comfortable in use, and with a 40-hour battery life, you won't want or need to take them off.

● ***$199*** ● ***www.audio-technica.com***

Reviewed: Vol. 24, No. 1, Page 86

› Sennheiser GSP 670

The freedom you get from going wireless is often overused in this industry, but where headsets are concerned, there is a real benefit to not being anchored to your desk. We'll admit that the GSP 670s are pricey, but the quality speaks for itself, and these produce an incredibly detailed soundstage, while also feeling luxurious, thanks to the headband that enables you to control how much pressure is applied to your head. The fact that you can connect using Bluetooth makes them versatile, too.

● ***$349*** ● ***https://sennheiser.com***

Reviewed: Vol. 24, No. 8, Page 88

› HyperX QuadCast

HyperX knows what it takes to make quality hardware, and the company has hit the ground running with its QuadCast microphone. Anyone who needs to capture audio at a better level than is possible with a headset mic should take a look at this excellently spec'd device. The shock mount does a brilliant job of keeping your voice clear of pops and whistles, and while it can't quite compete with professional studio equipment, it isn't far off.

● ***$140*** ● ***www.hyperxgaming.com***

Reviewed: Vol. 24, No. 6, Page 88

› Logitech G502 Lightspeed

We wish wireless gaming mice didn't cost as much as they do, but there is enough cleverness involved here that those wanting to treat themselves to a tail-free experience need look no further. It nails the basics—being comfortable and boasting an excellent sensor—but manages to couple that with great battery life and enough customization options to please just about any hand. It's absolutely riddled with buttons, and you can assign actions to the mouse wheel as well.

● ***$140*** ● ***www.logitech.com***

Reviewed: Vol. 24, No. 8, Page 86

› Roccat Kone AIMO

The price of gaming mice seems to be rising on a daily basis, which is why it's good to return to a wired mouse that doesn't cost as much as a decent case, and underlines what really matters for any budding rodent. The Kone AIMO has a quality sensor, boasts solid construction and materials, and has a less-is-more ethos that sees it nail the fundamentals. This is a big mouse, though, so those with smaller hands may need to look elsewhere.

● ***$80*** ● ***www.roccat.org***

Reviewed: Vol. 24, No. 2, Page 86

› Elgato 4K60 Pro MK.2

If you're planning on taking your streaming to the next level, you'll have come across the Elgato name, and for good reason—it's the standard for capture hardware. This, its latest offering, is capable of capturing 4K streams at up to 60Hz, or, if you'd prefer, 1080p at up to 240Hz, or 1440p at 144Hz. It's easy to get up and running, too: Slide it into your machine, connect your source (PC, Xbox One, Nintendo Switch, or PlayStation 4), and you're good to go. Easy and effective.

● ***$250*** ● ***www.elgato.com***

Reviewed: Vol. 24, No. 12, Page 86

A pack of perfect projects to get your Pi 4 journey off the ground. By Alex Cox

MASTER THE RASPBERRY Pi 4

The Raspberry Pi 4, the latest iteration of the world's most popular single-board computer, has dropped with a big impact, sporting a huge uptick in specifications that doesn't affect its credit-card-sized footprint. But once you've invested your $35, what are you going to do with that cut-price, cut-sized hardware? How do you exploit its abilities? We have a few ideas that use those new features—the gigabit Ethernet, upgraded CPU and GPU, 4K-capable dual HDMI ports—and make the Pi 4 shine.

It actually arrived a few months ago, but we've held off on taking a dive into the Pi 4's potential abilities because it hasn't been ready—the hardware leap from the previous generation hasn't been easy for software creators to catch up with, and its firmware has lagged behind a little. While things have improved, you need to go into this adventure knowing you might not yet be creating anything that's production-ready.

That said, there's still plenty to play with and a lot of benefit to be eked out of the miniature marvel. The Pi 4 is a feasible compact desktop computer at last. Its architecture—which includes USB 3 ports that no longer share a bus—lends itself to running as a custom NAS controller, a network appliance, or a TV media box. And as software support improves and that firmware firms up, as the key distros bring their full functionality to the Pi, there's a world of potential to explore.

New hardware is highly exciting, and the natural response to a spiced up Pi would be to abuse it to the max. So, why not use it as a full PC? Yes, it has always been technically possible to use a Pi as a functioning desktop PC. Even the Raspberry Pi 1 Model B, with its 512MB RAM and 700MHz ARMv6 CPU, could manage a rudimentary desktop, in much the same way as you can force a Commodore 64 to run a GUI or even a Linux analog if you're crazy. Of course, those with long memories will remember PCs of yesteryear running with far lighter specs, but they weren't the size of a credit card with a severely limited architecture.

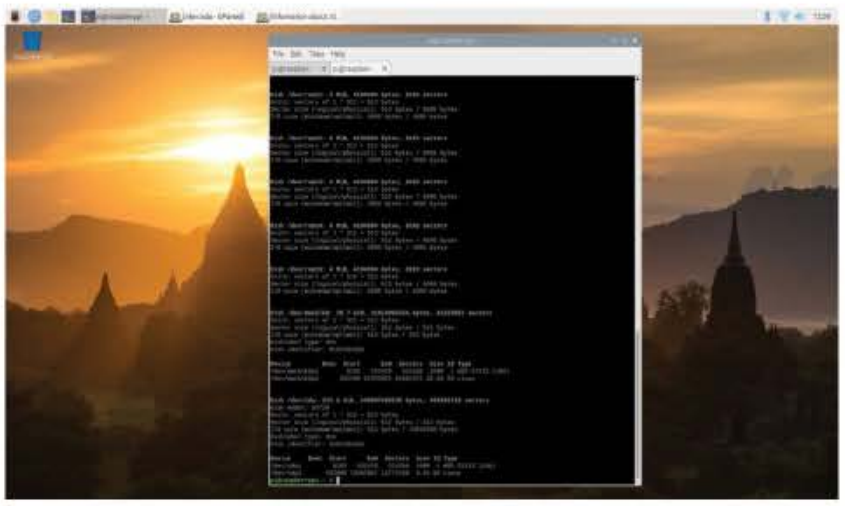
While there's been incremental improvement in the Pi's desktop performance over the years, the new hardware in the Pi 4 does away with the "technically possible" part of the equation: It is not just feasible to run a Pi 4 as a desktop machine, it is positively pleasurable, so much so that the Raspberry Pi Foundation is selling its own Raspberry Pi desktop kit. That new processor has enough muscle to fling around whatever you might throw at it, network and USB no longer share the same bus, there are multiple monitor outputs right there on board, and (depending on the spec you pick) your desktop OS can access up to 4GB RAM. Usually. Note that, so far, we've not been able to force Windows 10 on to a Pi 4, but given our experiments with doing so on a Pi 3—a 10-minute boot time and almost completely unresponsive desktop—we imagine it wouldn't be too fruitful. This is a Linux-only task.

Some caveats for the over-excited, before we get too involved. This will never replace your high-end desktop machine. That would be preposterous—it's a $55 bundle of electronics, not a $1,000 killer rig. Realistically, unearthing some old desktop hardware and slapping some variety of Linux on it will offer a much more capable and flexible experience. This isn't only because that hardware is typically much faster, with functions given to dedicated hardware on traditional PCs forced to run on single chip—or, worse, in software—on the Pi, but because the CISC architecture of x86 can take many more shortcuts than ARM's RISC layout. Speaking of which, the Pi's architecture restrictions haven't changed: Any software you run needs to be compatible with and compiled to run on ARM. Thankfully, there's a large library out there, and it's often possible (though slow) to build your own packages from source, if there's no ARM version available.

GET THE HARDWARE RIGHT

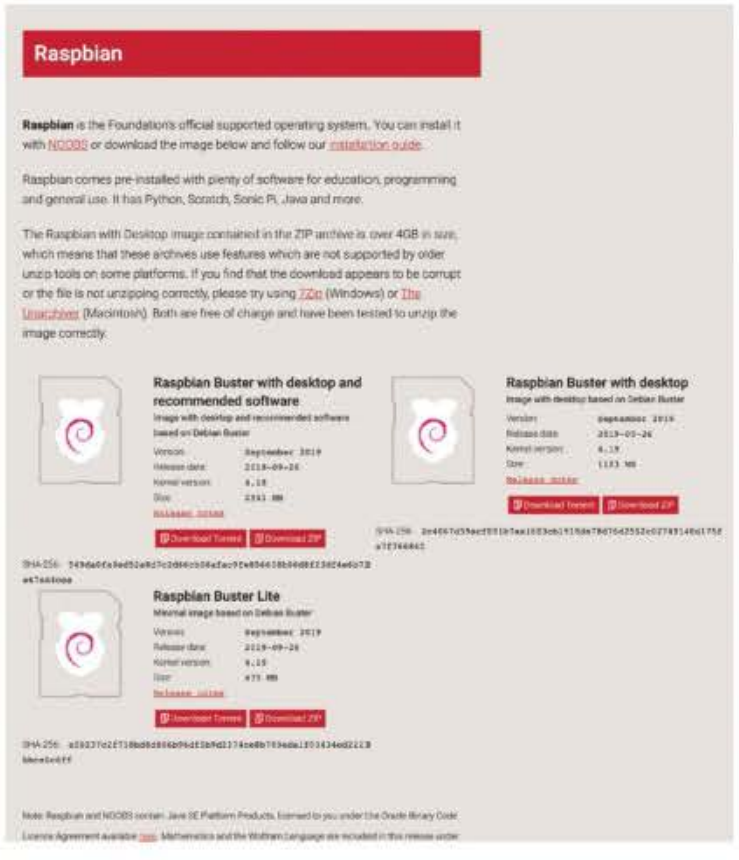
If you're going to use a Raspberry Pi 4 as a desktop PC, you need to make a choice: Do you opt for 1GB RAM (no), 2GB (possibly), or the most expensive Pi 4 build at 4GB? The latter would seem like a no-brainer, but at the time of writing, the Pi 4's firmware isn't super-reliable—some OSes, notably Ubuntu, can't take advantage of the full 4GB, requiring a hack that leaves you with less usable RAM. It's still more than 2GB, though, and that rocky start for the firmware isn't likely to continue forever, so we'd absolutely suggest a 4GB Pi for the task.

Next, controlling the thing. Peripherals aren't really a huge issue, even if they use heavy-drawing RGB, because the Pi 4 uses a 3A power supply, but it's worth considering compatibility. Linux's hardware management and driver support continues in the same slightly ropey vein it always has, meaning certain wireless devices aren't supported well. Don't think about switching out that official power supply for something else, though, because the Pi 4 lacks the relevant resistor to support smart charging supplies, and you could put your hardware at risk.



Raspbian runs the unique Raspberry Pi-specific PIXEL desktop environment.

Ah, Ubuntu. Good old Ubuntu. It doesn't work perfectly just yet, but it is Ubuntu. Ubuntu.


Raspbian
Raspbian is the Foundation's official supported operating system. You can install it with NOOBS or download the image below and follow our installation guide.
Raspbian comes pre-installed with plenty of software for education, programming and general use. It has Python, Scratch, Sonic Pi, Java and more.
The Raspbian with Desktop image contained in the ZIP archive is over 4GB in size, which means that these archives use features which are not supported by older unzip tools on some platforms. If you find that the download appears to be corrupt or the file is not unzipping correctly, please try using 7Zip (Windows) or The Unarchiver (Macintosh). Both are free of charge and have been tested to unzip the image correctly.
Raspbian Buster with desktop and recommended software
Raspbian Buster with desktop
Raspbian Buster Lite

The Raspberry Pi foundation offers a few different flavors of Raspbian.

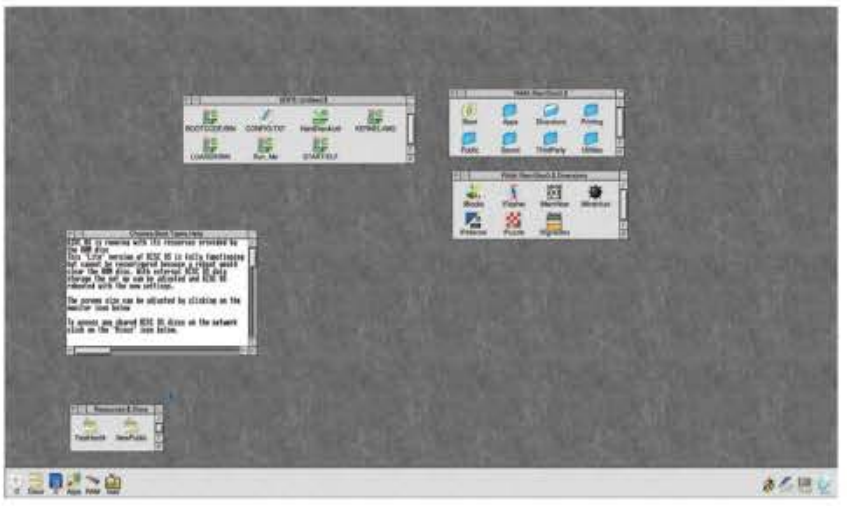
In terms of display output, the Pi 4 has a huge advantage in that it can comfortably support dual screens through its pair of built-in micro HDMI ports. Comfortably, that is, as long as you don't mind dual 4K screens being forced to run at 30Hz; 1080p, or a combination of one 1080p panel and one 4K, can hit the full 60Hz refresh rate. Dual screens really do give this a leg up on the previous generation, positioning it as a truly modern desktop, but while its enhanced GPU, a Broadcom VideoCore VI running at 500MHz, might be powerful enough to handle two screens, don't anticipate relying on that single-chip solution for heavyweight pixel-pushing tasks. Photo editing, perhaps, but video editing is plausible only in certain circumstances, specifically when you're working with the particular flavors of H.265 or H.264 that are natively supported by the GPU.

Storage is the big issue, at least at press time. As of the current firmware, there's no support for USB booting (unlike on previous Pis),

© WIKIMEDIA COMMONS

The MATE spin of Ubuntu is currently waiting on an update—count us excited.

Manjaro's LXFe version has a structure that'll be immediately familiar to Windows users.



You likely don't want to run RISC OS in anger, but it is (or will be) a neat nostalgic exercise.

© UBUNTU-MATE.ORG, MANJARO.ORG, RISCOSOPEN.ORG

The Pi 4 has a huge advantage in that it can comfortably support dual screens through its pair of built-in micro HDMI ports.

and running a desktop operating system from a microSD card—a format that is, beside its lack of speed or, potentially, space, liable to literally set itself on fire if tested too hard with this kind of work—isn't the best idea. USB boot is actually some way down the firmware roadmap, sitting somewhere behind network boot, but we can get a little clever: By putting just Linux's boot partition on the SD card, and shuffling everything else out to a USB-connected SSD, we'll avoid unnecessary wear and reliance on that microSD.

DESKTOPS, DESKTOPS

Which desktop OS should you choose? The Pi 4 improves on its predecessors by carrying an ARM v8, 64-bit processor, and any distro that can work with that (also known, in Debian lingo, as arm64, or in Fedora terms as arm-64) is worth at least a cursory look. ARM v7 builds should work fine, too. Let's look at the main candidates.

›› RASPBIAN The obvious option is Raspbian—it's the frontline Linux distro of the Pi, and the only distro officially supported by the Raspberry Pi Foundation. It's built on top of the Debian architecture, the same core structure used by Ubuntu, which means it has a whole host of available packages, and it naturally works well with the specific hardware of the Raspberry Pi 4. The latest version is Raspbian Buster, released in September 2019, and new versions tend to follow a biannual release.

›› UBUNTU The big boy of Linux, and the most hand-holding friendly, too, is supported on the Pi 4. Sort of. At press time (we're saying that a lot, and for good reason), the arm64 build has a rather painful bug that means USB ports don't work on the 4GB version without a rather unfriendly kernel-swapping fix, but older versions built for v7 chips will work—although, with those, you're stuck with 32-bit operations and limited memory, due to the 32-bit address space.

›› UBUNTU MATE A special flavor of Ubuntu that uses the MATE Desktop environment, Ubuntu MATE has long been a popular alternate Raspberry Pi desktop build—indeed, if you're running a Pi 3, it's the one we recommend. Right now, though (and it's worth checking ubuntu-mate.org for any changes), there's been no new version specifically for the Pi 4. When it does come, we imagine it'll run fantastically, with its low-demand desktop idling at around 490MB.

›› MANJARO ARM Moving away from Debian, Manjaro is based on Arch Linux, a lightweight distro apparently dedicated to a "keeping it simple" philosophy—mileage may vary with that claim. Manjaro ARM appears to work well, with versions available sporting both the LXFE and LXQt desktop environments, both of which are familiar and lightweight enough to give a decent desktop experience on the Pi 4.

›› OTHERS Down the line, we expect a whole host more desktop distributions to hit the Pi 4. Fedora ARM currently seems a little behind the curve, but we've seen confirmation that the devs are working toward a build for the new architecture. Similarly, FreeBSD (which isn't technically Linux) should get a Pi 4 version in time. The Raspberry Pi has long been the home of the resurrected RISC OS, which comes from ARM roots on the Acorn Archimedes, but a 64-bit version specifically for the Pi 4 would be a huge surprise—there has not, thus far, been any 64-bit release of RISC OS for any platform, and it would mean a major rewrite of the code. That said—and this is true for just about any OS mentioned here—there's nothing stopping you trying a 32-bit version. It is not as

You'll need a micro HDMI cable to hook up your Pi to a monitor or TV.

LOW-IMPACT APPS

Come, fill your tiny $35-$55 desktop PC with the kind of apps a PC of that value could never have dreamed of in days gone by. Show it who's boss. You're boss, in case you hadn't realized. In Raspbian, you'll want to click the raspberry icon, then head to "Preferences → Add/Remove Software" to find the packages.

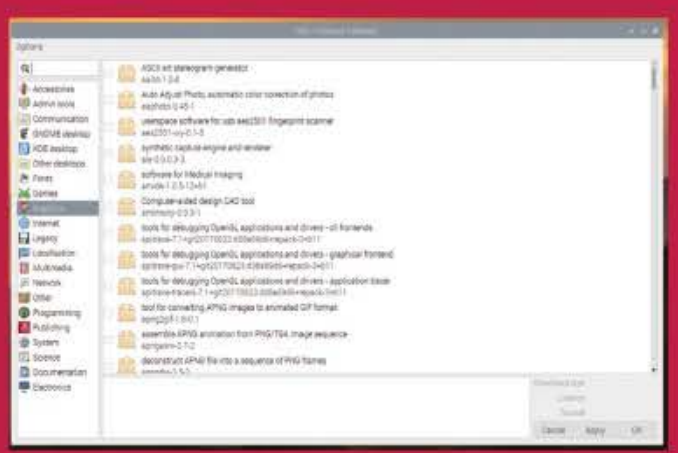
›› *OFFICE:* LIBREOFFICE
No sense in deviating from the open-source standard here, because the LibreOffice suite runs remarkably well on the Pi 4, particularly once you've made the transition to booting from an SSD. You'll find it preinstalled with most distros, including Raspbian.

›› *IMAGE EDITING:* GIMP
Another staple: The GNU Image Manipulation Program is a fantastic and extremely capable Photoshop-esque photo editor and graphics mangler that runs perfectly adequately on high-RAM editions of the Raspberry Pi 4.

›› *INTERNET:* CHROMIUM
We'll stick with Raspbian's default browser again, because it's pretty damn snappy, but bear in mind that Chromium's favorite thing in the world is your RAM, and each of its tabs are going to eat as much of it as possible.

›› *PRINTING:* CUPS
Whether you've got the correct drivers for the most common printer in the world or you're working with Linux on some obscure sub-model of a lesser-known laser, it's all a bit of a gamble. CUPS (the Common UNIX Printing System) is your best bet for getting those documents on paper.

›› *VIDEO:* VLC
OK, we're recommending VLC, because it works adequately well, but the Pi's speciality is not in decoding video, especially that which isn't H.264/H.265 encoded. There are ways, such as using Plex or Kodi, but sticking to online streaming (and, even then, to 720p) may be your best option.



Raspbian's Add/Remove Software tool is useful—though also spectacularly ugly.

A fast external SSD really dials up the snappiness of Raspbian on the Pi 4.

though the ARMv8 processor can't handle it. You lose access to some of your RAM if you've gone for the 4GB version, and many distros lack support for some of the Pi 4's functionality, but this is a platform based on experimentation.

INSTALLING AND RUNNING

Presuming you've chosen Raspbian, let's get you up and running with a system that boots from microSD and immediately jumps to an external SSD for storing and running the main bulk of the operating system. Start as you usually would, by downloading the latest fully loaded version of Raspbian Buster from http://raspberrypi.org/downloads/raspbian. Unzip, then head to http://balena.io/etcher to get the latest version of balenaEtcher, a super-simple disk imager. Write the Raspbian image not to your microSD card but to that USB drive—you will, it goes without saying, lose everything that's on there, so don't wipe a drive full of beloved content. Do the same thing again, but write the image to your SD card this time.

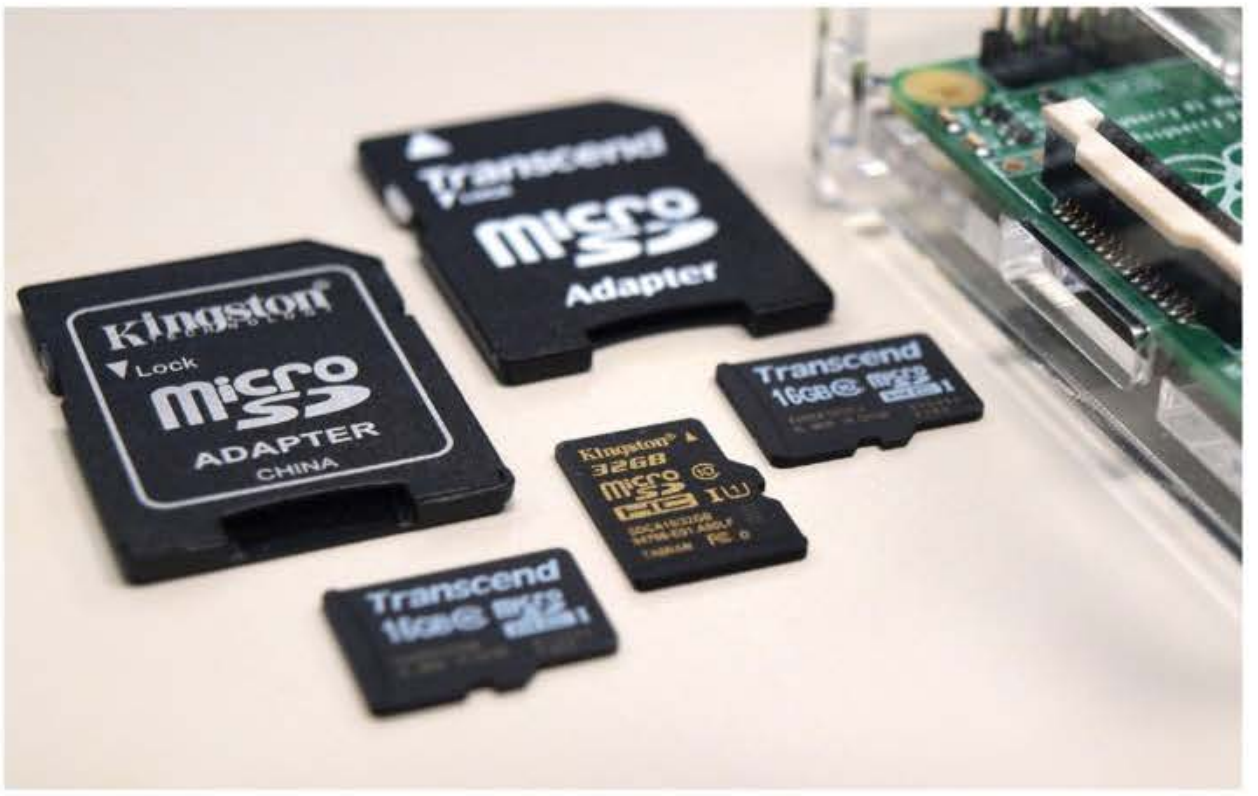
Insert the microSD card into your Pi and plug your drive into one of its USB 3.0 ports, wire everything else up, plug in your peripherals, and power on via the mains adapter. Once you've waded through the initial options, open a command line with the icon at the top of the screen, and run `sudo fdisk -l` to see a list of your attached drives. The Pi's default password is "raspberry" in case you need it. One drive, your SD card, will have a name beginning "mmc," while your USB drive (which is what we're looking for) will likely begin "sda." If it says "sdb," switch that out as follows.

Run `sudo nano /boot/cmdline.txt` to edit the options that are passed to the Pi when booting from that SD card and, at the end of the line, add `root=/dev/sda2 rootwait` to tell Raspbian that your main filesystem is on the USB drive. Exit nano (Ctrl-X, Y, then Return), and run `sudo reboot` to start your Pi again, this time (all being well), running from the USB drive. The main tell is that you need to set everything up again—if you previously connected your Wi-Fi, or run through the initial setup procedure, all of that is returned back to the defaults written to your USB drive.

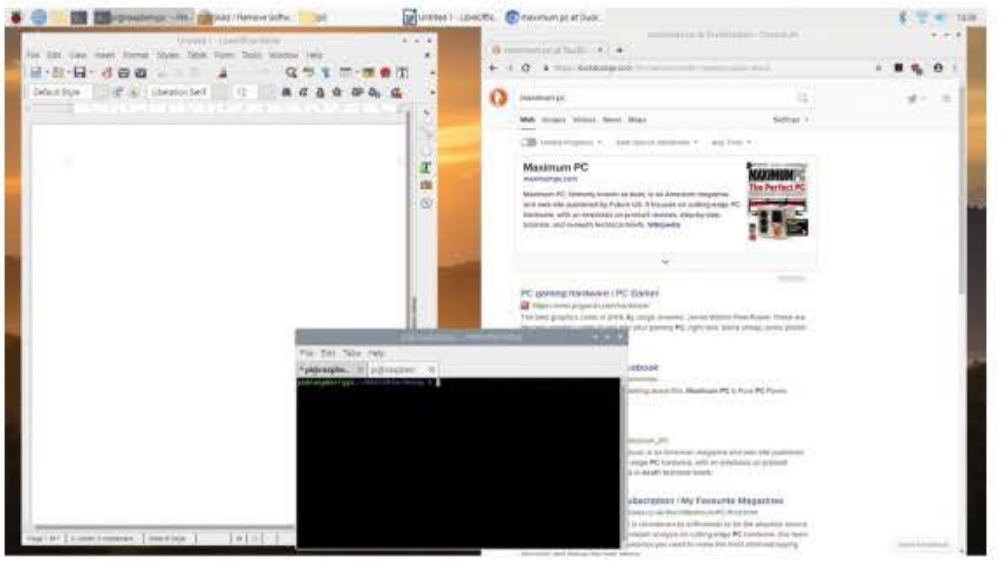
There's a problem, though: You basically have no space on that drive, because the partition is written to be only as large as it absolutely needs to be. Run `df -h` in the command line and you'll see—the /dev/root/ partition just ain't big enough. The `raspi-config` tool that would normally do this only wants to work with SD cards, so let's modify it: Run `sudo cp /usr/bin/raspi-config ~` to copy it to your home directory, then run `sudo sed -i 's/mmcblk0p/sda/' ~/raspi-config` and `sudo sed -i 's/mmcblk0/sda/' ~/raspi-config` to switch it to accessing the device at "sda," then run the version in your home directory with `sudo ~/raspi-`

One of the Pi's biggest stumbling blocks is gone: The USB and Ethernet ports no longer share the same bus, restricting the speed of both.

© DEBIAN PROJECT, SAMSUNG



MicroSD cards are nice and all, but they're really terrible storage for running an OS.



The Pi 4, particularly with 4GB RAM, offers up enough strength to run a desktop with few compromises.

Below: **Passive cooling can go a long way with the right case.**

`config` . Head to option 7, then select "Expand Filesystem."

Restart with `sudo reboot` and run `df -h` again—you should see a marked difference in available space. Make sure, when booting your Pi in the future, that you use the same SD card and keep the USB drive in the same physical port, to avoid any potential problems. All being well, this won't be a workaround we have to do forever, but for now, you're free to start filling that drive with software and get working.

NAS-TY BUSINESS

There's been some realignment in the Pi's hardware, which means one of its biggest stumbling blocks is now gone: The USB and Ethernet ports no longer share the same bus, restricting the speed of both. The Pi 3's gigabit Ethernet, tied to a USB 2.0 bridge, could only reach 300Mb/s—this new version now runs at true gigabit speeds. The flip side of the coin is that there are also now two ports of glorious USB 3.0 to work with—we took advantage of one with the SSD boot process, but we can also use these ports in conjunction with that higher network throughput to use the Pi as a rather competent network attached storage device.

Optional, but recommended if you're planning to roll this out

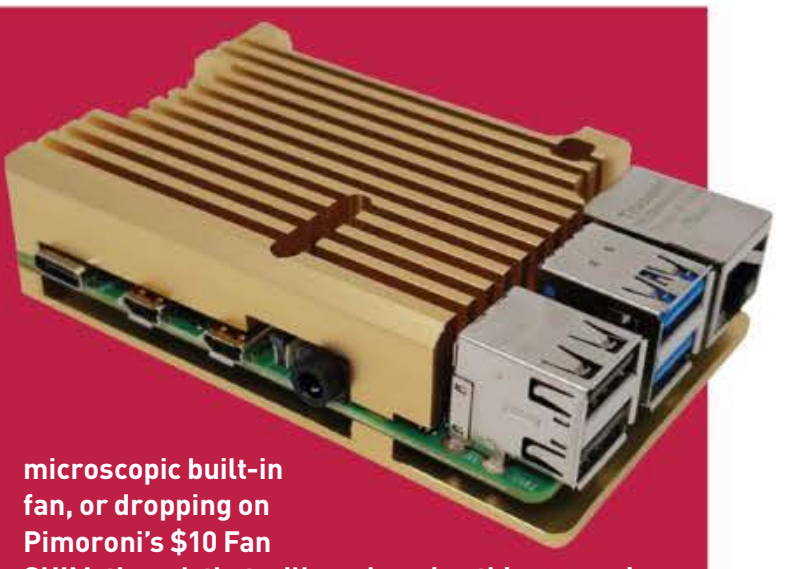
KEEP IT COOL

The Raspberry Pi 4 is unusual in its company, because it's a warm little thing. We've seen users out there experiencing recorded temperatures of around 82 C sitting idle, which is (as you might imagine) not the finest thing to happen to your hardware.

Like most chips these days, the key components of the Pi 4 will thermal throttle when they get too hot: The CPU is set to throttle at 80 C, while the GPU joins it should the temperature make it to 85 C. If either of these things happens, you'll see a thermometer pop up on your desktop, half full to represent the former situation, and full red when everything's going into slow-down mode.

This mainly happens because these chips are being pushed. ARMv8 runs much harder and hotter than the cores of Raspberry Pis past. The first couple of editions could run happily with no cooling at all; the Pi 3 realistically necessitated a small heatsink on the major chips; run the Pi 4 raw, and you're in a world of hurt.

So, a case is an absolute must. Irritatingly, the official red and white case from the Raspberry Pi foundation just compounds the problem, encasing the board in a toasty box that keeps it nice and insulated. You don't absolutely have to go to the full extent of using a case with a microscopic built-in fan, or dropping on Pimoroni's $10 Fan SHIM, though that will obviously keep it cool enough; the Aluminum Heatsink Case from The Pi Hut ($15) does a highly credible job of dissipating the heat from across, the board while still keeping things passive and silent.



If you want to see how hot your board is getting, run `sudo vcgencmd measure_temp` in a command line to return your core temperature.

© PI HUT, GTWANG.ORG

NEXT-LEVEL NAS

If you'd like slightly more complexity to your NAS than a simple Samba share, look in the direction of OpenMediaVault, and cross your fingers that it gets updated to the Pi 4 soon. It's a much more complex and fully-featured NAS solution, with a web interface that lets you do the dirty work of setting it up and allows you to access files on your server from outside your local network, if you set it up correctly. It also offers access to services like SSH and FTP, allows you to run torrents on your NAS box, and much more.

While there's no official build for the Pi 4 yet, you can download an entire single-purpose OMV distro for its elder siblings at https://sourceforge.net/projects/openmediavault, which you just need to write to a card with Etcher—as with all these not-officially-compatible projects, you're welcome to try it to see whether the current 32-bit version works for you. OMV's distro is based on Debian, which has been proven to at least vaguely work with the Pi 4, so you should be able to run it without too many hardware conflicts.

Run through the installation when connected to a mouse, keyboard, and monitor, logging in with the default username "root" and password "openmediavault." Use the command `ifconfig` to determine your Pi's network address, and head to the OMV web interface from another machine on the same network by dropping that location into a browser address bar. Logging in as "admin" with the same password should get you in, and you can start configuring straight away. No guarantees, though: A few months' more Pi 4 maturity should get you a version directed at the new board.

OMV offers a whole host of functionality and an easy-to-use interface.

Want a toolkit for white hat hacking? Kali Linux is ideal. Behave yourself!

as a serious storage solution, is a powered USB hub to ensure your drives never drain the Pi of too much precious energy when worked hard. Truthfully, you probably don't need it, but something like TP-Link's UH720 ($30) offers up a whole raft more ports as well as adding power, meaning you can expand your central storage as additional drives become available.

You don't need the all-inclusive Raspbian package for this—the Lite version will do, and you won't need to keep it hooked up to a monitor or any peripherals, as we'll be able to control it remotely, though for the sake of ease of setup, we suggest you hook everything up at least until the NAS is up and running.

Let's tick off some prerequisites: Write Raspbian Buster Lite to your card, boot it up in your Pi, then run `sudo raspi-config` from the shell. In "Interfacing Options," switch on SSH, so that you'll be able to access the shell using a tool such as PuTTY later on, set up your Wi-Fi if you're going to use that, change your password (because leaving the default password on a device you're going to deliberately leave open on the network would be a drastically foolish move), then head to the "Network Options" page. We recommend changing the host name to something like "nas" so it's easily found later.

There's a ton of ways we could go about this. You could, with enough drives, set up a mirrored RAID 1 array using the tool `mdadm`, presenting them as a single drive. We'll sidestep that for now—it's a little excessive, and unless you have your Pi hooked up to a UPS that is going to ensure it never loses power, there's a good chance Linux's overly-sensitive file handling will lead to the array's demise sooner rather than later. If you do want to use it, install it using `apt-get`, consult its man page (`man mdadm`) for instructions, and (once installed) use /mnt/raid1 or similar when referencing the storage drive.

The simplest solution would be to take advantage of Samba, Linux's Server Message Block (SMB) network sharing tool, which will give us a simple storage area that shows up as a network drive in Windows. First, get your drive (or drives—repeat the following as necessary) ready. Insert your storage device into the Pi, and Raspbian should mount it automatically; run `lsblk` to see what drive designation it's given it—in our case, this is /dev/sdb. You need to initialize the drive and give it a partition Raspbian can work with; fdisk is our friend for this task. First, unmount any partitions lsblk listed using `umount /dev/sdb1` or similar. Now run `sudo fdisk /dev/sdb`, hit N when prompted to create a new partition, and if you're told one already exists, hit D to delete it, then N again to create a fresh one. You'll want a primary partition (P), then just hit Return until you get back to the base command prompt. Hit W to write the changes, and your disk is initialized—repeat this for any other drives you might be using.

Now format the drive with `sudo mkfs.ext4 /dev/sdb`, create a mount point for it using `sudo mkdir /mnt/sdb`, and mount it with `sudo mount /dev/sdb /mnt/sdb`. It's important if we're setting up network storage that this drive gets mounted to the same point every time, so let's set it to happen at boot by running `sudo nano /etc/fstab` to edit the static filesystem table. Insert the following on a new line, separating each entry with a tab:

```
/dev/sdb    /mnt/sdb    ext4
defaults    0    0
```

Exit nano, and it's time to set up Samba—a mercifully simpler procedure. Install it with `sudo apt-get install samba samba-common-bin`, then run `sudo`

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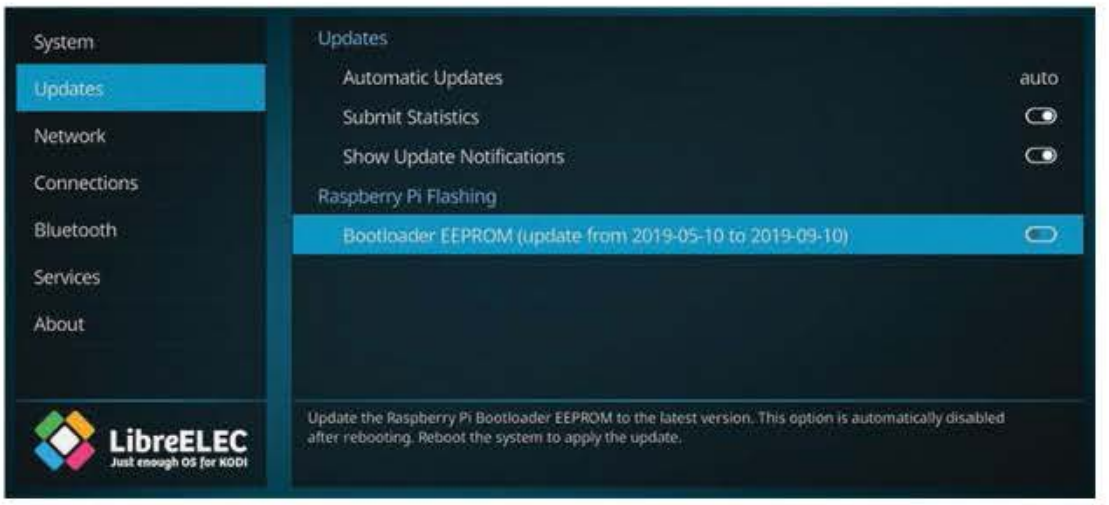


Librelec's Kodi implementation includes extra Pi-specific tools and options.

PiHole's statistics show just how much nefarious online tracking it's blocked.

`nano /etc/samba/smb.conf` to edit its configuration file. Head to the bottom of the file, and add the following to define the parameters of your share:

```
[storage]
path = /mnt/sdb
writeable=Yes
create mask=0777
directory mask=0777
public=no
```

Of course, all of this assumes you want to use a whole drive for network storage—you can just as easily use a folder on an existing drive. Simply make one in your home directory with `mkdir ~/share`, and switch it out for the drive's mount point in the above instructions.

Now we can set up our Samba user—it's a better idea to do this than leaving "public" set to "yes," for the security of your files. Run `sudo smbpasswd -a max` to create a user named "max" and you're prompted for a password. Restart Samba with `sudo systemctl restart smbd` and you are ready to go—connecting to your NAS should be as simple as mapping a network drive in Windows and pointing it at \\nas\storage.

When you later come to administer your storage box, if you've disconnected the monitor and peripherals, you'll need its IP address—use `hostname -I` now and make a note of it.

EVERYTHING ELSE

You'll notice that we're in a tough spot with the Pi 4. Its hardware makeup isn't difficult, but it's different—so different from previous minor-iteration Pis that rolling old projects on to the new board hasn't been possible. So, let's look at where we're at with some of the more popular single-use scenarios, and discuss what you can hope to expect.

›› MEDIA BOX Unusually in the company, LibreElec—which dubs itself "just enough OS for Kodi"—has kept pace with the Pi 4, and appears to be getting regular updates. That makes setting up a Pi 4 as a Kodi box absolutely trivial. Head to http://libreelec.tv, grab the Raspberry Pi 4 image from the downloads section, and write it to a card with Etcher. There's a whole seedy streaming subculture of Kodi that we won't go into, but bear in mind the Pi 4's hardware decoding capabilities: If you want to watch 4K media files on your TV, they need to be in H.264/H.265 format for the best results, so convert them beforehand with a tool such as Handbrake.

A Pi with a decent amount of storage is perfect for Plex Media

STEAMED PI

You could, if you were particularly masochistic, attempt to install Steam and find ARM-compatible games on the platform to play on the Pi. Our brief experiments show that would not work well. Or you could do the sensible thing and use it as a Steam Link, streaming games from your main PC to your living room TV. This function has been disappointing on previous models, but it works tremendously well on the newest Raspberry Pi. A Pi running the Steam Link app is functionally equivalent to Valve's outdated Steam Link hardware, only dialed up to 10: The Pi is a much more powerful device.

The app has been updated for the fourth-generation Pi—just run `sudo apt install steamlink` to install it—but we'd say it still has a little way to go. The old techniques for running it automatically don't yet work, so you need to keep a keyboard and mouse connected to your Pi to launch it when the time is right, and the current implementation is tied to H.264 streaming. The Pi 4's hardware makeup caps H.264 at 1080p, which means the app isn't able to stream games in 4K, despite the gigabit Ethernet port clearly being capable of handling the amount of data required.

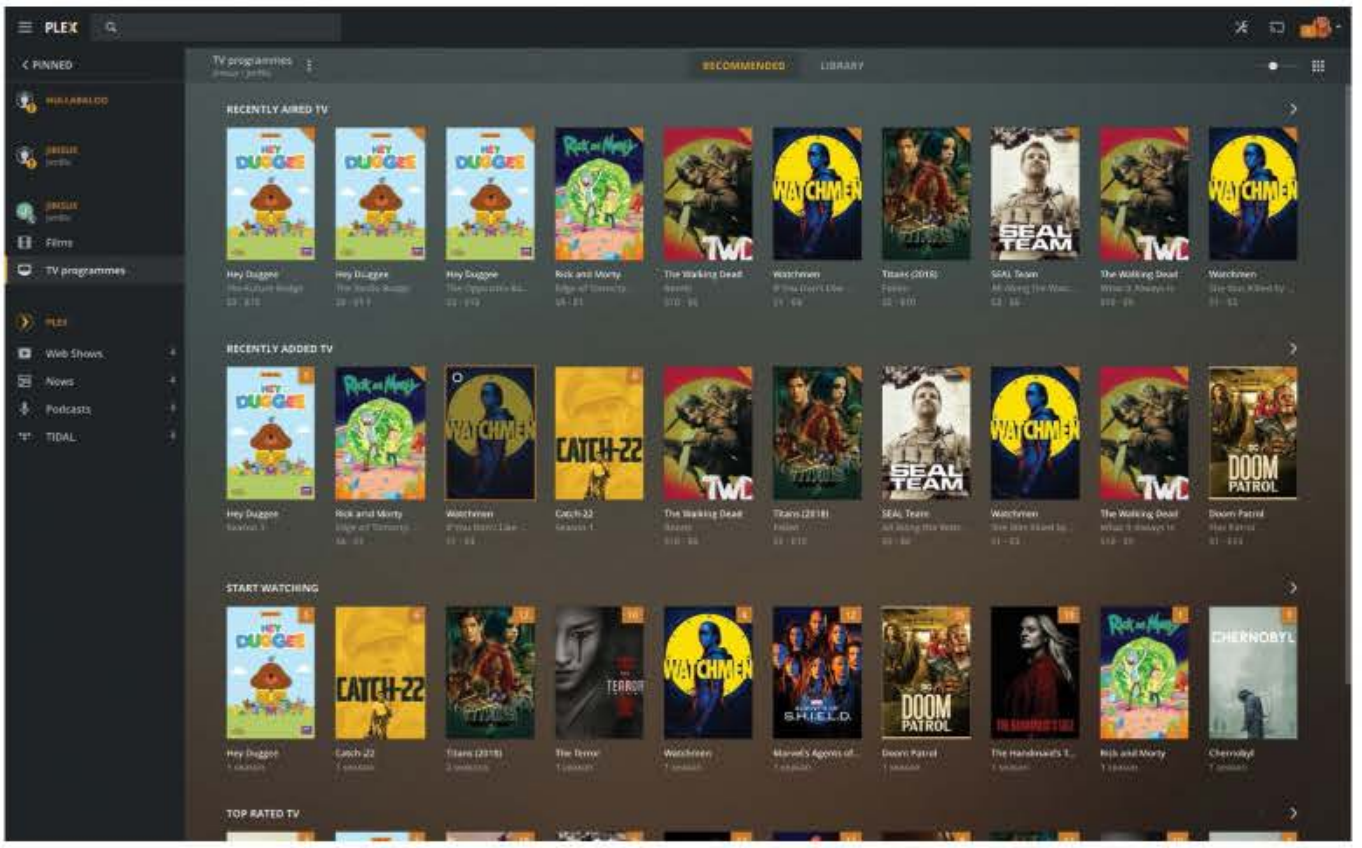
Valve may have discontinued the hardware Steam Link, but it continues to support the software version. There's no reason the streaming stack won't get an upgrade to support H.265 in the future, so keep an eye on it if you're looking to exploit that new TV to its full extent. Alternatively, Nvidia's Shield ($149) coupled with GeForce Now on your PC can comfortably stream 4K games over your network, and it's a significantly more elegant solution to get the job done.

Get the Big Picture experience on the kind of screen it's meant for.

© VALVE, LIBRELEC, PIHOLE

Server. It's not necessarily the best at transcoding that media, but it can. Hosting it and streaming it around your network and beyond is fully plausible, but you may find your CPU getting hammered and the Pi heating up hugely. Thankfully, at least the most recent version is happy to work with the Pi 4.

Run `sudo apt install apt-transport-https -y` followed by `curl https://downloads.plex.tv/plex-keys/PlexSign.key | sudo apt-key add -` to grab the Raspberry Pi PGP key. Then run `echo 'deb https://downloads.plex.tv/repo/deb public main' | sudo tee /etc/apt/sources.list.d/plexmediaserver.list` to tell your package manager where to get Plex's files, `sudo apt update` to update its knowledge of said files, then `sudo apt install plexmediaserver` to install it. Once it's done, you'll be able to log in to its web interface, and get it configured using localhost:32400 on the Pi, or substituting "localhost" for your Pi's IP address on a remote machine.



Plex is basically roll-your-own Netflix, assuming you have a large amount of media.

›› RETRO GAMING It's fair to say that the only reason many people own a Pi at all is RetroPie (http://retropie.org.uk), the all-in-one package that pulls together emulator support for just about every classic system, and adds a neat front end with which you can select (legally obtained) ROMs. Right now, the system image for RetroPie is built on top of Raspbian Stretch, an older version of the OS with no support for the Pi 4, and RetroPie's creator specifically notes that it will not work.

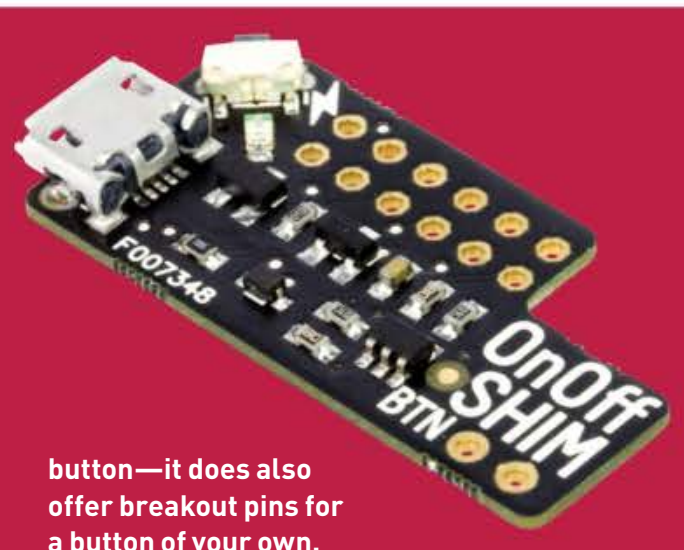
This is a shame, particularly as that the Pi 4 has the muscle to run Dreamcast, N64, and PSP games at close to original speeds, but not all is lost. You can run emulators such as RetroArch yourself, or you can simply install the RetroPie package (which contains the equivalent of what's included in the system image) on top of Raspbian itself. Execute `sudo apt-get install git lsb-release` to install some prerequisites, then use `git clone --branch fkms_rpi4 --depth=1 https://github.com/RetroPie/RetroPie-Setup.git` to download the installation script. Jump into the directory with `cd RetroPie-Setup`, use `chmod +x retropie_setup.sh` to tell Linux you want to execute that file, then run it with `sudo ./retropie_setup.sh`.

Alternatively, you can try Lakka, the official Libretro distro—it's not officially released yet, but you can grab the latest version from http://

HARDWARE HEAVEN

While we've mostly covered the Raspberry Pi here in its role as a computer, there's a duality to it: It's as much a hobbyist hardware platform as it is mini PC. Thankfully, the Pi 4's hardware shift has not affected its GPIO pins, which are laid out in the same way as the whole range, from Pi Zero up, so the entire world of Pi HATs is available to those open to experimentation. Whether you want to add a dedicated LCD, e-ink, or TFT display, add arcade control to your emulation box, upgrade its audio output with a dedicated DAC, or give yourself a convenient platform for electronics tinkering, there's something for you.

We wouldn't call any HAT absolutely essential, but something that adds an actual hardware power switch to the Pi should be high on your list, particularly if you're running headless, because powering down a Pi by yanking out the USB connector is a tremendously bad idea for your data. A SHIM (which, charmingly, stands for "shove hardware in the middle") is a great choice for this, because it won't interfere with any HATs you've placed on top of it. Pimoroni's OnOff SHIM (around $8) is a great choice as long as your case gives room for you to reach its small momentary button—it does also offer breakout pins for a button of your own. All it takes is a little one-line software command to install the clean shutdown script and protect your Pi from data loss.



The OnOff SHIM is an easy way to make sure you power off properly.

Of course, you don't have to use a SHIM—those pins are yours to play with. If you want to write your own shutdown script, and wire the right pair of pins to a button or switch of your own, you can.

© PIMORONI, PLEX

How tough is your network? The Raspberry Pi 4's compact size makes it a strong candidate to run as a discrete penetration tester.

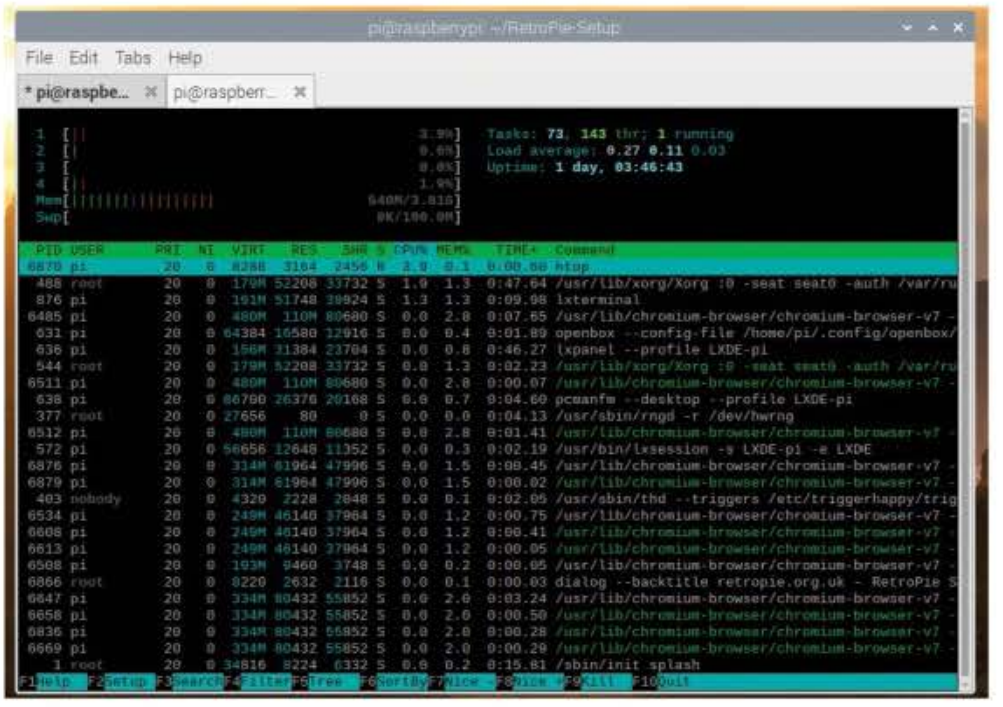
nightly.builds.lakka.tv. Drill down to the "RPi2.RPi4.arm" directory, and grab the "img.gz" file, which you can burn as usual using Etcher. It's bleeding edge so, like running RetroPie on top of Raspbian, expect a litany of bugs.

One more option: DOSBox. While you're hard pressed to translate anything x86 on to the ARM architecture of the Pi, DOSBox is an exception. If you're interested in running classic old games, just run `sudo apt-get install dosbox` to download and install it.

›› NETWORK TOOL A Pi with a hardened network interface, faster processor, and more generous dollop of RAM makes it a powerful candidate for running network tools. PiHole, for example, is a DNS sinkhole, a network-wide ad blocker that pulls ads and trackers out before they even have chance to reach your devices. It's spectacularly simple to install (just run `curl -sSL https://install.pi-hole.net | bash` from your Raspbian Buster shell), and requires only a little router fiddling to get in order. You need to make sure your router points to your Pi as its primary DNS server, rather than whatever your ISP supplies, and give PiHole a static IP address, a task left as a rather cruel challenge for you.

You could also use your Pi as a network monitor. NEMS, the Nagios Enterprise Monitoring Server (http://nemslinux.com), is as heavyweight as its name suggests. It can watch all of your network services and alert you if something goes bad, offers a web interface to show you the current network status, and it supports plugins, so you can extend its capabilities. Everything's rolled into a neat distro available to download and write to a card, and as it can be a little intensive on the Pi 4's resources, that single-use format suits it well.

How tough is your network? The Pi's compact size makes it a strong candidate to run as a discrete penetration tester, and Kali Linux—Offensive Security's tool-packed pen-testing distro—was one of the first to support the new hardware. Download it from http://offensive-security.com/kali-linux-arm-images and write it to a card as usual—but be careful, because these are tools that really shouldn't be used on anything other than your own hardware. If you take your Raspberry Pi out of the house and begin a reign of cyber terror, we can't be held responsible.


pi@raspberrypi: ~/RetroPie-Setup
File Edit Tabs Help
* pi@raspbe...
pi@raspberr...
Tasks: 73, 143 thr; 1 running
Load average: 0.27 0.11 0.03
Uptime: 1 day, 03:46:43
PID USER PRI NI VIRT RES SHR S CPU% MEM% TIME+ Command
F1Help F2Setup F3Search F4Filter F5Tree F6SortBy F7Nice - F8Nice + F9Kill F10Quit

How stressed is your Pi getting? Run htop on a command line to find out.

A customizable touchscreen Stream Deck would be cool.

OVER TO YOU

The Raspberry Pi is all about experimentation—so why not put together your own project? Here are some things we'd love to see; let us know if you've built a distro, come up with a combination of packages, or spotted something we've missed that can give the Raspberry Pi these capabilities.

›› A MUSIC MAKER
How about wiring up a series of arcade buttons to the Pi—à la the Midi Fighter, or the MPC—and using them to trigger samples? We'd need superlow latency to use it as a live instrument, knobs to tweak things as we play, and an easy way to add samples—maybe pulling them from whatever USB stick is plugged in.

›› A CHROMECAST CLIENT
Yes, you could just buy a Chromecast for less, but that's not the point; a Pi that shows up on your network as a Chromecast would be super-useful, particularly if you could pair those capabilities with local media playback, and keep a file server running, too. A Chromecast is just a Chromecast—a Pi is so much more.

›› VIDEO VISUALIZER
You can already employ a HAT, such as the ReSpeaker, to cook up your own Amazon Echo-style smart assistant with the Raspberry Pi, but how about using it for something a little more fun? We want those twin mics to feed into a WinAmp-style video visualizer to throw some serious shapes on to a projector at a party—and, please, throw in audio jukebox capabilities, too.

›› STREAM DECK CLONE
The Stream Deck, from Corsair's now-subsidiary Elgato, is a cool but rather pricey tool for streamers, which uses a grid of OLED buttons to help you switch between scenes—we see no reason why a Pi with a touchscreen couldn't be exploited in the same way.

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THE STATE OF VR

Join us as we take a look at the current state of virtual reality in gaming and beyond

BY CHRISTIAN GUYTON

VIRTUAL REALITY keeps coming back, like a bad smell. Or a nice smell; a pleasing scent of sandalwood for the proponents of VR, as they insist that it's "the future of gaming" or "the next level of immersion." Some of us at *Maximum PC* are skeptics, while others think VR just hasn't quite hit its stride yet. There are applications beyond gaming, too, with virtual reality headsets now being used in medical and architectural fields.

The problem is that there have already been a few "futures of gaming." First it was webcam body-tracking, then it was motion controls, then it was touchscreens, then it was motion controls again, then it was, uh, figurines with NFC chips in them? Yeah, we don't know what Nintendo was smoking when it dreamed up the Amiibo, but the point is that gimmicks like VR have been a part of gaming for a long time, and most of these fads have fallen apart.

Virtual reality has stuck around for longer than most, with the industry currently in its "third phase" of VR products. The technology is improving significantly, too, with newer headsets, such as the Vive Cosmos and Oculus Rift S, claiming to offer superior motion tracking, graphical fidelity, and immersion. The amount of money being poured into VR projects has certainly risen in recent years, with even Facebook swooping in to buy up big VR business Oculus for a staggering $2.3 billion in 2014.

Where is VR heading, though? Examining the history of the industry demonstrates a lack of innovation since the initial introduction of modern VR headsets. While the hardware has improved, the way VR works hasn't really developed, and there's yet to be a killer app that makes VR headsets a must-have product. So, we're left asking: What's next for virtual reality?

© GETTY IMAGES

BURGERS
BYTES
JOB-TEMBER

VR TECHNOLOGY has been around since the '90s, with the earliest commercial attempt being Sega's brief demonstration at the Consumer Electronics Show in 1993, which was then canned before release. A few other manufacturers took a shot, most notably Sony, but the technology wasn't quite there yet. The experience was fraught with latency issues and tunnel vision, and while it was a hopeful portent of things to come, most gamers weren't exactly blown away.

Fast-forward a couple of decades, and we find ourselves in the mystical, futuristic land of 2012. Plucky tech startup Oculus began a Kickstarter campaign to crowdfund its advanced, high-end Rift VR headset, designed by Palmer Luckey, with the support of id Software co-founder John Carmack, a big proponent of VR. The fundraising campaign was massively successful, raising more than 10 times the original goal of $250,000. The finished product was released to consumers in 2016, and was immediately popular, although the initial retail price of $599 meant sales were hardly through the roof.

It was a successful innovation, though, and everyone wanted a slice of the VR pie. Sony came back with a vengeance, giving its successful PlayStation 4 console a VR headset, the inventively named PlayStation VR. Cell phone manufacturer HTC partnered with Valve to produce its own contender, the HTC Vive. The competition was fierce, although primarily between HTC and Oculus; Sony's offering was console-specific, as opposed to the PC-oriented applications of the other two.

Surprisingly, Sony came out ahead; the PSVR was and still is the single most successful system-tethered VR headset ever, selling over four million units in three years, thanks to a lower initial price, compatibility with Sony's existing PS Move motion controllers, and an assurance that the headset would work perfectly with the static PS4 hardware. Oculus

Palmer Luckey, the original creator of the Oculus Rift, has since left the company.

outsold HTC by a small margin on its first release units, but both the Rift and Vive shared the same problem: needing to work with a wide variety of consumers' PCs, both pre-built and custom systems.

This is an issue that has plagued the majority of VR headsets designed to work with PCs. The uncertainty as to whether their rig can support a VR platform drives potential buyers away. With the PSVR, it was simple: If you have a PS4, you can use it. With PC-tethered VR headsets, consumers had to ensure that the system they had was capable of running games in VR—and with a huge variety of custom-built machines in the homes of PC gamers across the globe, that became a problem.

GOING MOBILE

Of course, the companies behind VR were aware of this, and working on solutions. Oculus produced the Oculus Go, a PC-less offering that went without wires thanks to an integrated Qualcomm chip to handle graphics. It wasn't incredible in terms of graphical fidelity, but it sold well, even exceeding Rift sales in some markets. The more powerful follow-up, the Oculus Quest, was released recently, and you can find our review of it in this very issue.

A different strategy was employed by Samsung, which collaborated with Oculus to corner a slice of the market with a super-cheap solution: a VR headset with a slot for a Samsung Galaxy smartphone, which acted both as a screen and CPU. It sort of worked; the GearVR headset contained its own hardware for motion controls and head tracking, and at less than $100, it was far more affordable than other options, although it did require the user to own a Galaxy phone.

GearVR sold well, shifting five million units, and spawned legions of imitators of varying degrees of quality. Slightly before its release (but long after Samsung's plans for the GearVR were conceived), Google announced Google Cardboard, a hilarious but undeniably effective VR solution that consumers could buy or even build themselves from cardboard. It used the same smartphone-oriented ideas as the GearVR, but was even cheaper and less sophisticated—because, well, it was made of cardboard. Google put out its own proper answer to Samsung's GearVR, Google Daydream, a few years later.

WHERE NEXT?

While all of these products did well, none set the world alight. Google Daydream

© FORTE, SAMSUNG

From left to right: **Forte's VFX1 was one of the earliest attempts at VR, using a weird hockey-puck-shaped controller. The original Oculus Rift was a true game-changer for VR. Samsung and Oculus worked together to produce GearVR, a cheaper alternative to full VR headsets.**

READ OUR **OCULUS QUEST** REVIEW ON **PG. 80**

***EVE: Valkyrie* was one of the first major VR titles, demonstrating the power of the hardware.**

was discontinued earlier this year, while GearVR hasn't had a new hardware announcement since 2017. PSVR has remained a constant, a good metric of how well VR as a whole is performing, although as the release of the PlayStation 5 looms, it seems likely that Sony may take a moment to evaluate the direction it wants to head regarding VR.

John Carmack himself was recently decorated at the third annual VR Awards, receiving a lifetime achievement award for his work with Oculus. However, during his acceptance speech, he noted that he and some of his colleagues "really haven't been satisfied with the pace of progress" with regard to VR development and expansion. He also admitted that VR is still an incredibly niche market, and remarked that there was a lot of work "yet to be done" before VR could properly hit its stride. Since then, Carmack announced he was standing down from Oculus to focus on artificial intelligence projects instead.

As far as we're concerned, he's right; VR seems to be stagnating. Oculus released the Rift S in early 2019, and a few months later HTC shot back with its Vive Cosmos. Both were quality, high-end headsets, but with more of a focus on improved hardware specs than genuine innovation. Improved camera tracking, higher resolution screens, and so forth; all good improvements, but useless without top-notch software to match it. The biggest change made by the Vive Cosmos is a reworked headset design that enables the wearer to raise the "visor" without removing the whole headset.

Even Oculus, arguably the progenitor of the modern VR headset, isn't moving rapidly. The Quest and Rift S aren't rethinkings of VR, just upgrades to existing tech; like the PSVR and Vive Cosmos, they're not pushing the VR industry forward in a meaningful way, even if they are great products. The problem with VR's failure to expand might lie elsewhere, then, perhaps more on the software side.

BLAME THE GAMES

A common opinion is that VR is lacking a killer app; that one game or program that is a genuine game-changer. So far,

© NINTENDO, CCP GAMES

***Right:* The HTC Vive has remained Oculus's main competitor in the VR market.**

VIRTUAL ORIGINS

VR has been kicking about for a while in various forms. Perhaps the most memorable precursor to modern VR was Nintendo's oft-maligned Virtual Boy, a table-mounted headset that demanded you press your eye holes into it to experience wonky stereoscopic 3D games in all their red-tinted 32-bit glory. It was frankly horrible, and a huge commercial failure for Nintendo.

The Virtual Boy (pictured above) might be a familiar industry touchstone, but it wasn't a true VR headset; the focus was on headache-inducing parallax 3D. Sony's Glasstron visor was a true predecessor of VR as we know it today; a proper head-mounted display that enabled gamers to take a seat in the cockpit of a war machine in *MechWarrior 2.* Sony released five models of the Glasstron across three years in the '90s, and while they weren't a huge success, they would set the stage for Sony to produce PlayStation VR nearly 20 years later.

Some smaller companies tried to take a stab at VR before the turn of the century, too, none leaving much impact. In Britain, IBM-funded company Virtuality Group experimented with VR headsets in arcades, and some have argued that the arcade is the perfect setting for VR; a chance to try out games and experiences in virtual reality, without having to fork out hundreds of dollars for the hardware. In fact, modern VR headsets aren't an uncommon sight in arcades today, although the decline of arcades in general doesn't bode very well for that avenue of success.

It's difficult to chart how exactly the history of VR led to Palmer Luckey's Oculus Rift prototype in 2012. It was a fresh start; an effort to revive VR with the new technology of the day. And it worked. VR was back with a bang, ready to enter a new golden age, only to grind to a halt again as the buzz of excitement died down, and the harsh realities set in.

GAMES WORTH PLAYING

For every good game playable in VR, there are about 7,000 bad ones, based on our expert (not exactly accurate) calculations. Those good games do exist, though. Right off the bat, we've got to recommend *Beat Saber,* a high-octane, neon-tinted rush of adrenaline—*Guitar Hero* by way of *Star Wars.* Your two controllers become lightsabers as colored blocks race toward you, demanding that you destroy them in time to the music. Similarly fast-paced is bonkers extreme sports game *Sprint Vector,* which sees up to eight players race through all manner of futuristic locales at blistering speeds.

Those interested in a more cerebral experience might enjoy *Budget Cuts,* a tongue-in-cheek stealth title that puts you in the shoes of a human employee in a workplace full of robots. Armed with a portal gun and office supplies, you sneak around, hiding from camera-headed bots. It's got a brilliant, dark sense of humor that reminds us of the original *Portal.*

Black comedy seems to work well in VR, for some reason. *Duck Season* takes you back to a childhood in 1988, where you're eager to play the newest hit game—a thinly veiled *Duck Hunt* rip-off. However, it quickly becomes clear that something is awry inside the *Duck Season* cartridge, with strings of horror, action, and stealth gameplay complementing the opening arcade shooter elements.

***Arizona Sunshine* and *Space Pirate Trainer* are both enjoyable bouts of zombie- and robot-blasting respectively, while the fantastic *SUPERHOT* is even better in VR. It brings a glorious sense of mastery when you *Matrix*-dodge out of the way of a bullet, throw a bottle at your assailant, and snatch their dropped gun from the air to finish the job. It's as much a puzzle game as it is a shooter, and it feels as good as it looks.**

Beat the crap out of angular red men with improvised weapons in *SUPERHOT.*

***Gorn's* exaggerated bodies and showers of blood look great in VR.**

that hasn't materialized. A few cool ideas, such as Samsung's 360-degree camera for immersive video experiences, were eventually laid aside as gimmicks without staying power. Until the technology behind VR can be perfected to provide total, unbreakable immersion, the onus lies on the software to carry the format forward.

Here's the sad thing: Current VR games are a sorry bunch. There are a few real gems out there (check out the "Games Worth Playing" box), and some full-fledged AAA releases have been retooled for VR with varying degrees of success, such as the excellent *Skyrim VR* or the slightly wonky *Borderlands 2 VR.* But as a general rule of thumb, good VR games need to be built from the ground up to work in VR, and most developers won't dedicate the time and money to make that happen on a large scale.

Plenty of people are willing to take a stab at producing a game for VR, though, perhaps just out of the novelty of it. What this leads to is a wealth of titles that are short games at best, glorified tech demos at worst. Many developers seem to begin with a unique, interesting idea for a game that would work well in VR, but lack the resources to produce it in any form that lasts longer than two hours. Some are insultingly short; *Accounting+,* a game from *Rick and Morty* star Justin Roiland, is hilarious, well crafted, and less than an hour long. And it costs $12!

The alternate approach has been to produce virtual sandboxes for gamers to simply mess about in. This is the bread and butter of so many YouTube and Twitch channels—nonsensical tomfoolery in a variety of settings, often employing a key mechanic to keep things interesting. *Blade and Sorcery* puts players in a medieval arena and arms them with a range of era-appropriate weapons and magical spells for beating the living daylights of hapless goons. *Gorn* does a similar thing, but with cartoonishly proportioned gladiators and ridiculous, over-the-top gore.

FINDING THE FORMULA

Fooling around in VR is fun enough, but these games don't have storylines, objectives, or even really any quantifiable amount of game content. *Pavlov VR* is a lot of fun with some mates, as you mess around with automatic weapons in a facsimile of *CounterStrike,* but it quickly starts to feel more like a demonstration of what VR is capable than an actual game.

Indeed, virtual reality "experiences" are commonplace, enabling VR headset owners to immerse themselves in another life for a short while—all too often, a very short while. That could be a gun range, a rollercoaster, even a plank overlooking an 80-story-high fall. We're not going to talk about the sexy ones; we leave that to less refined journalists. But the point is that VR "games" often aren't games at all, merely snapshots, glimpses into exciting worlds and scenarios that are snatched away almost as soon as they begin.

Even some of the "proper" games released for VR are lacking in content, polish, or simply quality. One problem with virtual reality is that games come in a huge variety of genres, many of which simply don't work in VR. That said, some genres fit excellently with the format of VR. Puzzle games can work excellently in virtual reality, particularly locked-room puzzles, such as the comedic spy jape *I Expect You to Die.*

First-person shooters work relatively well in VR, enabling players to pull off maneuvers that would be impossible within the confines of a conventional

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FPS. Driving and flight sims can be fantastic, dropping the player into the cockpit of an F1 car or an awesome spaceship, providing static immediate surroundings while the environment moves around the player. Meanwhile, the extra layer of immersion generated by VR has led to some fantastically scary horror games—*Resident Evil 7: Biohazard* is a particularly jump-scare-fraught delight.

THE END OF VR?

VR isn't beyond saving. But it feels like we may be approaching a critical juncture; the make-or-break point for this generation of VR, where the format will either evolve and continue or collapse, presumably doomed to return in another decade or so when the technology has evolved.

It's hard to see how a single game could fix the problems with VR at this point, though. VR might need a killer app, but it may not be enough. Industry veterans are still divided on whether VR is really the direction in which gaming is headed, and even tech titans such as Facebook and Google have proven unwilling to sink huge amounts of money into VR projects. Valve, meanwhile, has committed to another bout with it recently-released Index VR.

Oculus is showing no sign of stopping either, with the Oculus Quest supposedly being the final product in its first generation. It's hard to see right now how the second generation will be quantifiably different, though, beyond minor improvements to the displays and processing power of the new headsets.

If VR is left alone to chug along without real support, it will die. Overpriced hardware and a dearth of proper games have already hamstrung the platform's worth to serious gamers, and super-cheap alternatives could actually have hurt the marketing narrative of VR by convincing many consumers that it's a one-off gimmick, fun for half an hour before you put the cardboard headset down, and go back to using your phone like a normal human being.

Honestly, we'd really love to see VR turn around. The potential is there, and modern headsets provide a far more convincing experience than pre-2010 attempts. But unless developers prove willing to band together and properly push the value of the hardware with new, bigger, more involved games, we don't see it happening. Perhaps the success of VR is inevitable; like cloud-streamed gaming or motion controls, it's one of those USPs that comes back around every few years to have another attempt at success. Whether we'll see it now, or have to wait until the 2030s, is anyone's guess.

A US Navy medic uses a VR parachute training simulator.

BEYOND ENTERTAINMENT

VR isn't just for gaming, of course. Indeed, Oculus creator Palmer Luckey parted ways with videogames to found a new company specializing in defense technology, putting that VR know-how to work on drones, sensors, and software for the US military. Virtual reality has been examined by numerous militaries worldwide for training purposes, particularly for fighter pilots, where it enables them to experience combat situations without any exposure to real danger.

Virtual reality has also been used for medical purposes. Trainee surgeons can practice complex operations in VR, or rewatch 360-degree videos of more experienced surgeons at work. VR headsets have even been used for experimental therapy purposes, such as a program that simulates the effects of dementia on a person's vision and hearing. Applications such as this can allow family members to see things from the perspective of a relative suffering from a mental health condition.

Another, slightly more esoteric, use of VR tech has been in the fields of archeology and paleontology. Archeologists can map out dig sites using drones and cameras to produce digital copies of the locations, enabling students and scholars all around the world to tap into them and explore areas in virtual reality. As you might have guessed, the next logical step is to recreate those sites as they would have looked in their prime, creating a portal to the past for academics and enthusiasts alike to experience historical locations as they should be.

The uses don't stop there. Some businesses have adopted VR for virtual meeting rooms to connect employees in different offices, while architects have used it to demonstrate what their finished building will look like. Perhaps the future of VR isn't in gaming and entertainment at all, but in the world of work instead....

The Oculus Go was one of the first mainstream attempts at an all-in-one wireless VR headset.

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HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH

ADJUST YOUR COMMAND PROMPT WINDOW

You can customize the look of your Command Prompt window by opening it up (search for it in the "Start" menu, if you don't know how), right-clicking the top bar, then selecting "Properties." This enables you to alter all sorts of elements, from font and text size to colors and command history. Most helpfully, you can adjust the opacity, enabling you to view other windows while you bash away.

CHRISTIAN GUYTON
STAFF WRITER

EXPLORING VR

I've been spearheading our investigations into the state of the VR market, and it's been fascinating to re-acquaint myself with virtual reality. I used to think of it as a fun side project for the games industry, something most people couldn't afford to get into, but a platform that would chug along next to mainstream gaming.

Now I'm not so sure. VR needs to innovate, and the industry needs to band together if it wants to keep VR alive—on PC, at least. Sony's PSVR is hugely successful, and as a PS4 owner, it's a tempting prospect every time it goes on sale. But the PC VR market is crowded; Oculus and HTC have been butting heads for years, while newcomers, like the Valve Index, only serve to clutter VR storefronts, dividing developers with lucrative exclusivity deals that hurt the core conceit of VR.

The worst part is that VR feels as though it could be great. It's not perfect, but there are moments when I feel like I'm glimpsing a *Ready Player One*-esque world of glorious immersive entertainment. Landing a long-range crossbow shot in *Journey of the Gods*, catching airborne projectiles in *SUPERHOT*, even something as simple as waving to a friendly robot feel good in VR. Sadly, though, I suspect we've got a while to wait until VR tech becomes what it was meant to be.

MAKE – USE – CREATE

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Build your first nginx reverse proxy

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Machine of the month: Atari ST, and how to emulate it

70
Put together a powerful system for VR experiences

↘ submit your How To project idea to: comments@maximumpc.com

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IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

Microsoft Surface Pro X

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products.
To learn more, visit www.ifixit.com.

This SSD looks super-familiar. A quick comparison with the 256GB drive we pulled from the Surface Laptop 3 confirms both devices are using the same drive. Standardization is great for repairs!

Under the knife (and heavy-duty suction cup) this time is Microsoft's latest addition to its Surface range.

The screen comes clear with some serious suction, but we didn't have to reach for the heat gun, which is a bonus.

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BACKGROUND

Less than a month after dropping the Surface Pro 7, Microsoft is back with the Surface Pro X—a fresh design with hints of improved repairability. Since ripping into the Surface Laptop 3, we're cautiously optimistic. Bring on the era of repairable tablets, Microsoft—we're ready.

MAJOR TECH SPECS

- 13-inch PixelSense 2880x1920 display (267ppi)
- Microsoft SQ1 3.0GHz ARM CPU (based on Qualcomm's Snapdragon 8cx), with a Microsoft SQ1 Adreno 685 GPU
- 8GB of LPDDR4X RAM (16GB optional)
- Removable 128GB SSD (256GB or 512GB optional)
- 5MP and Windows Hello front-facing cameras, and 10MP rear-facing camera
- 2x USB-C ports and one Surface Connect port
- Wi-Fi 5 802.11ac, Bluetooth 5.0, Gigabit LTE

KEY FINDINGS

- Unlike the Surface Pro 7, the Pro X is a complete redesign. Compared to the Pro 7, we note the Pro X's rounded corners, narrower profile, and reduced port selection.
- With the kickstands raised, we can see that the Pro X gets a sleeker hinge, and there's the faint outline of what can only be described as a secret trap door. Beneath, an SSD (held down by a T3 screw), and a SIM slot. The SSD looks familiar. A comparison with the 256GB drive we pulled from the Surface Laptop 3 confirms both devices use the same drive. Unlike the Laptop 3 with its hidden screws, we don't find any fasteners lurking under the kickstand.
- We try a little suction to lift the display near the speaker grille, and we can cut right in. No goopy tendrils hold this display down—it comes off clean. This friendly, cuttable foam adhesive is an improvement over other Surface Pros, and pretty much all tablets with glued-down screens.
- We need only a single Torx bit to twirl away the heatsink screws. Here's one thing we're glad Microsoft didn't change: All the screws so far are just Torx. That was the previous Surface Pro's sole positive repairability point, and it's good to see it return. Supporting the heatsink is an interesting bit of abstract art. With the heatsink and quite a few shields and screws out of the way, the motherboard slides out.
- It seems that Microsoft has placed at least one foot on the repairability train—between this Pro X and the Laptop 3, we can hardly believe all the repair-focused changes it has made. The SSD is truly user-replaceable, requiring only a SIM eject pin and a T3 driver—no need to remove the screen. That's awesome to see in such a slim form factor. As a bonus, it's the same SSD as in the Laptop 3, so more standardization and better support from third parties.
- Repairability Score: 6 out of 10 (10 is easiest to repair). The user-removable SSD makes for easy upgrades and data security that doesn't require device destruction. To the extent that screws are used, they are all standard Torx fasteners. Many components are modular and can be replaced independently. Almost all repairs require display removal, with an improved procedure that needs no heat, but necessitates careful prying. The battery is glued in place, with its connector pinned under the motherboard—requiring near-total disassembly for service.

Build Your First Reverse Proxy

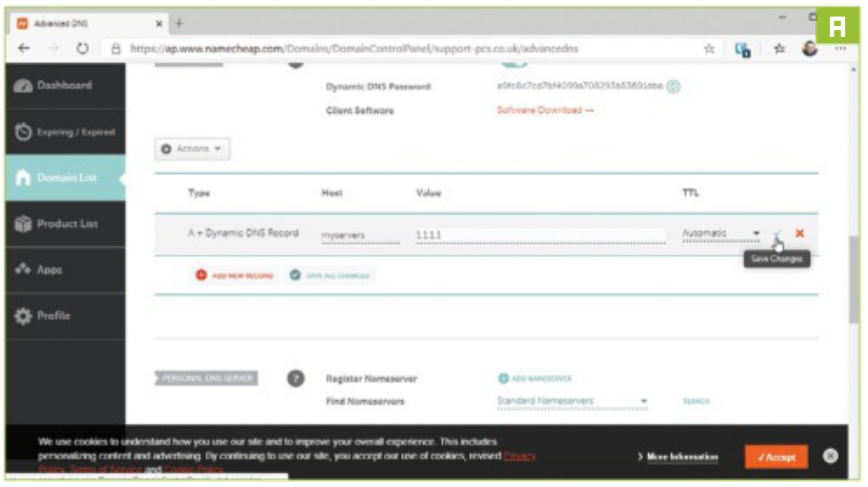
YOU'LL NEED THIS

DEBIAN-BASED LINUX
This includes Ubuntu or the Rasbian on the RPi, and you also need your own domain name. Windows 10 users can follow this tutorial using the Linux Bash Shell (see the box opposite).

OVER THE PAST FEW ISSUES, we've shown you how to build a few practical self-hosted servers: NextCloud for cloud storage, Bitwarden for password management, and Booksonic for audiobook collections, to name but three. While it's possible to configure all three for remote access over the Internet, it's an awkward process ensuring each individual server has access to a secure, encrypted Internet connection.

One of the many uses for a reverse proxy is to act as an intermediary between the Internet and any self-hosted servers you want to access remotely. Simply configure your router to forward all relevant ports to your reverse proxy, and it does the rest. Why do this? Because your reverse proxy secures all incoming and outgoing connections, making it easy to obtain and manage a free SSL certificate that encrypts traffic from all your self-hosted servers from one convenient location.

In this first of a two-part series, we're going to set up the nginx reverse proxy with a free, self-renewing Let's Encrypt SSL certificate to give you secure access to your NextCloud server from anywhere in the world. Next issue, we'll explore more configurations, plus delve deeper into other uses for your nginx reverse proxy. **–NICK PEERS**



1 SET UP YOUR DOMAIN

Your reverse proxy requires a domain (such as "yourname.com") that you use to "dial" into your services while on the road. If you already have one, we recommend logging on to your domain provider's control panel, and setting up a dedicated subdomain for the task—for example, "myservers.domain.com." You need to investigate ways of pointing this subdomain to your home network's public IP address (the one you get when typing www.whatsmyip.com into a browser when you're at home and not connected through a VPN).

›› In NameCheap, for example, click "Manage" next to your domain name under "Domains," then verify the domain is using a supported DNS (typically Namecheap Basic DNS) before selecting the "Advanced DNS" tab. Scroll down to "Dynamic DNS" and click "Add New Record." Enter your choice of subdomain ("services" in our example) in the "Host" field, and your home network's current public IP address in the "Value" field. Leave "TTL" set to "Automatic" and click the check mark [**Image A**].

›› Once created, typing your new subdomain into your web browser will attempt to connect you to whatever device on your home network is currently accepting connections from port 80. If it's your router's administration page, now is the perfect time to switch that feature off, for obvious security reasons.

›› If you don't currently have a domain, use a Dynamic DNS hostname from a provider such as No-IP (www.noip.com), which offers a range of free addresses—how about "yourname-services.myddns.me," for example? All you need to do is manually renew the hostname every 30 days.

2 FINISH SETTING UP PREREQUISITES

Your public IP address may change over time, so it's important that you follow any instructions to ensure your subdomain is updated whenever your public IP address changes. Both Namecheap and No-IP offer free software downloads, but check your router or NAS: QNAP owners should investigate the "Network & Virtual Switch → DDNS" setting, where a handy template for No-IP and other major DDNS hostname providers exists. It's the ultimate set-it-and-forget-it solution.

›› Next, you need to assign the PC running your reverse proxy a static IP address. To do this in Linux, open the terminal, and type the following command:

```
$ sudo nano /etc/network/interfaces
```

›› Locate the DHCP reference ("eth0" in our example below), and change it to the following lines, before saving and closing the file:

```
auto eth0
iface eth0 inet static
    address 192.0.2.7/24
    gateway 192.0.2.254
```

›› Windows users should assign a static IP through Windows itself via "Settings → Network & Internet → Change connection properties"—click "Edit" under "IP settings."

›› Once done, open your router's configuration settings in your browser, and locate the port forwarding section—it may be labeled "Virtual Servers" or something similar. You need to create two rules to divert all web traffic on ports 80 (HTTP) and 443 (HTTPS) to the same ports on your proxy server's IP address [**Image B**].

3 INSTALL NGINIX

We're using the well-known nginx (www.nginx.com) software in conjunction with Certbot (https://

certbot.eff.org) to get a free, self-renewing SSL certificate from Let's Encrypt to improve security. Installation on Linux is simple and quick:

```
$ sudo apt-get update
$ sudo apt-get upgrade
$ sudo apt-get install nginx
```

» If you're using Bash in Windows 10, you need to perform a couple of extra steps:

```
$ cd /etc/nginx
$ sudo nano nginx.conf
```

» Add the following line beneath "user www-data;":

```
master_process off;
```

» Save (press Ctrl-O followed by Ctrl-X), and then issue the following command:

```
$ sudo service ngnix start
```

4 AUTOSTART NGINX AND TEST CONNECTION

Nginx runs in the background, but while it automatically restarts when you reboot a native Linux server, it's not set to do so in Windows. Once you're happy everything's working to plan, you can have it autostart with Windows by issuing the following command:

```
$ sudo update-rc.d nginx enable
```

» To stop it autostarting in both Linux and Windows, issue a `sudo update-rc.d -f nginx disable` command instead.)

» Once installed, open a web browser, type your chosen domain into the Address bar, and hit Enter. If all is working as it should be, you'll see a "Welcome to nginx!" message appear. You should also test the connection from outside your local network—try connecting through your phone's cellular network or set up and connect to your router's guest Wi-Fi network, making sure it's configured to be isolated from the rest of your network.

5 INITIAL CONFIGURATION

All subsequent nginx configuration is done by editing a single file:

```
$ cd /etc/nginx/sites-available/
$ sudo nano default
```

» You'll see the configuration file is text-based, and consists of several enclosed blocks of code: server { location {} }. You'll need one server block per service you plan to make available over the Internet, as well as generic ones to cover web-based connections on ports 80 and 443. More on that later.

» First of all, you need to add your domain name to the configuration file—this will enable you to add the Let's Encrypt SSL certificate in the next step. This is added inside the first {server} block that's set to listen on port 80. Now scroll down until you find the line reading "server_name _;" which you should change to the following:

```
server_name myservers.domain.com;
```

» Obviously, substitute "myservers.domain.com" with your subdomain or DDNS hostname.

» After making changes and saving your file, test your changes by issuing the following command:

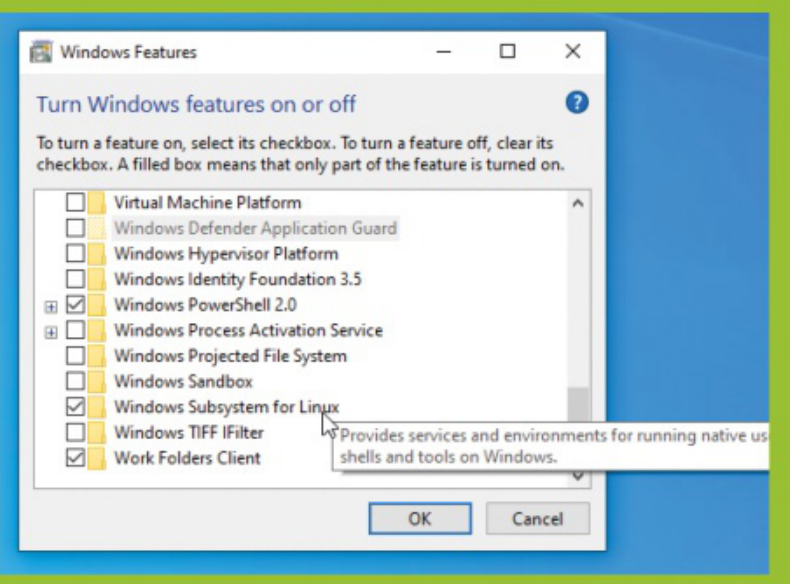
```
$ sudo nginx -t
```

» If it fails, reopen "default" in nano, and check your syntax for any errors. Otherwise, you can now restart the nginx service for real to apply your changes. Linux users can issue the following command:

```
$ sudo systemctl reload nginx
```

» If you're running Bash in Windows 10, you should use the following command instead:

```
$ sudo service nginx restart
```

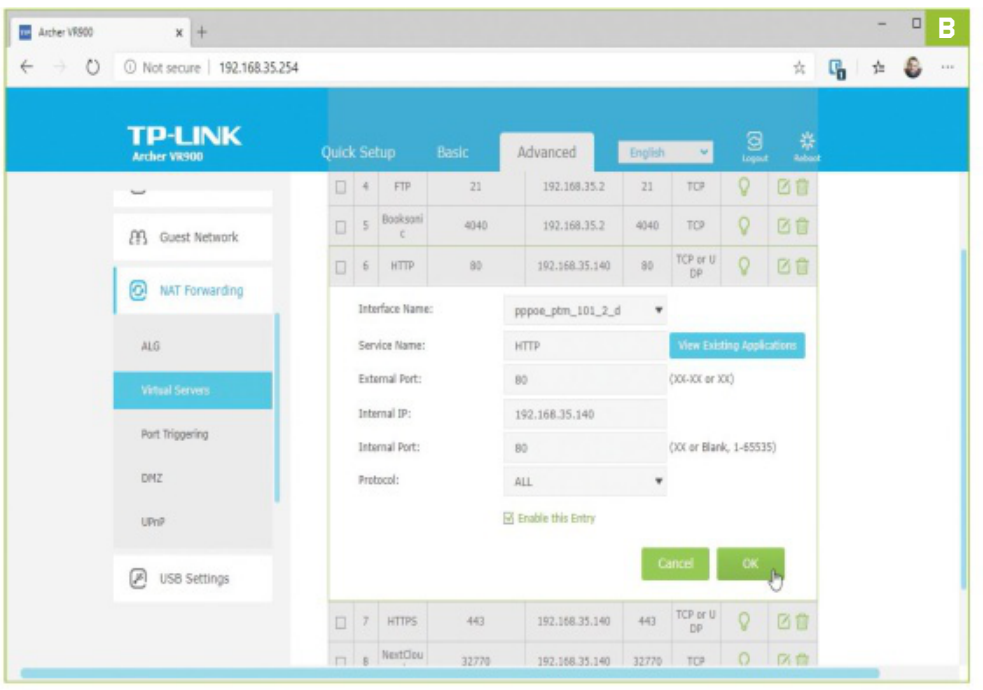

Windows Features
Turn Windows features on or off
To turn a feature on, select its checkbox. To turn a feature off, clear its checkbox. A filled box means that only part of the feature is turned on.
Virtual Machine Platform
Windows Defender Application Guard
Windows Hypervisor Platform
Windows Identity Foundation 3.5
Windows PowerShell 2.0
Windows Process Activation Service
Windows Projected File System
Windows Sandbox
Windows Subsystem for Linux
Windows TIFF IFilter
Work Folders Client
Provides services and environments for running native us
shells and tools on Windows.
OK
Cancel

WINDOWS REVERSE PROXY

There are several ways to set up a reverse proxy in Windows. In most cases, however, your Windows PC is your primary machine, and there are many good reasons not to be using that; it's best to keep the reverse proxy isolated, which is why you should consider running a virtual instance of Debian or Ubuntu. VirtualBox is perfect for the task—just remember to set up bridged networking to ensure the VM receives a proper IP address, so it's seen on your network.

If you're determined to run nginx in Windows, there is a Windows client, but as you'll see from http://nginx.org/en/docs/windows.html, it's not as fully featured as the Linux version. It's also not easy to link with a Let's Encrypt SSL certificate. Thankfully, you can follow the tutorial using Windows 10's support for the Linux Bash Shell.

Type "Windows features" into the "Search" box, then click "Turn Windows features on or off." Scroll down and check "Windows Subsystem for Linux," then click "OK," and reboot when prompted. Next, open the Microsoft Store to find and install Ubuntu 18.04 LTS. Once complete, click "Launch" to initialize it, before creating a user account when prompted. Once done, follow the rest of the tutorial.



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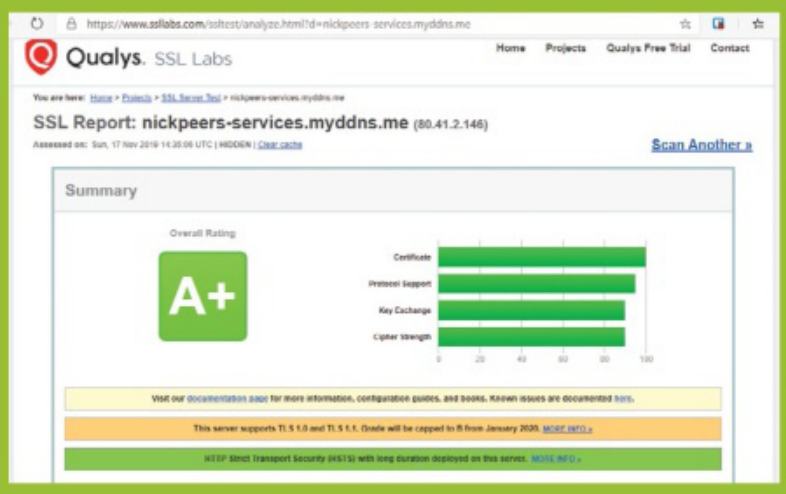
TIGHTEN SECURITY



When opening your network to the wider Internet, remember to stay secure. We've tightened security to some degree on the reverse proxy itself—by forcing use of TLS 1.2 and TLS 1.3—and you can make things even more secure by following guides like that at Raymii.org (https://raymii.org/s/tutorials/Strong_SSL_Security_On_nginx.html). That's the beauty of reverse proxies—rather than having to strengthen each individual server, you can add an extra layer of protection for them all. Apply these tweaks to all your server blocks, including the one set to listen to port 443 by default. Visit www.ssllabs.com/ssltest/ to see how secure your reverse proxy really is.

You should strengthen the security of each service you open for Internet access. Avoid non-secure (HTTP) connections, and ensure your accounts are protected by strong passwords. Look for options to block brute-force attacks—either natively, or (as is the case with NextCloud) via the Brute-Force Settings app.

Where possible, add additional forms of authentication—for example, NextCloud users can install the TOTP app to add 2FA authentication, then check "Enforce two-factor authentication" in "Settings" under "Administration → Security."

6 INSTALL SSL CERTIFICATE

We're going to add and manage our required Let's Encrypt certificate using Certbot:

```
$ sudo apt-get install python-certbot-nginx
```

» Once installed, reopen the "default" file in nano, and insert the following {location} block inside the {server} block set to listen on port 80 [**Image C**]:

```
location /.well-known {
        alias /var/www/html/.well-known;
    }
```

» Save and close the file, then reload nginx as before. You are now ready to request your SSL certificate—one command should do it:

```
$ sudo certbot certonly --webroot -w /var/www/html/ -d
myservers.domain.com
```

» Follow the prompts—once it's done, your certificate keys and files will reside under /etc/letsencrypt/live/myservers.domain.com.

» Once installed, you'll want Certbot to renew the certificate before the 90 days are up. Add the following line to crontab (`sudo nano /etc/crontab`) to instruct Certbot to renew your certificate after 60 days:

```
20 4 * * * root certbot renew --quiet --renew-hook "systemctl
reload nginx"
```

» Windows users should substitute `systemctl reload nginx` with `service ngnix restart` .

7 DEMAND SECURE-ONLY CONNECTIONS

Back we go into the "default/nginx.conf" configuration file. This time, you want to edit the {server} block listening on port 80, so it only listens for secure connections. Comment out any listen commands for port 80, and uncomment the two "listen 443" lines beneath them. You'll also need to add additional lines to make use of the Let's Encrypt certificate you generated earlier. The annotation opposite reveals the most secure setup to follow, but if you're in a hurry, the following lines will suffice for now—place them beneath the "server_name" line:

```
    ssl_certificate /etc/letsencrypt/live/myservers.
domain.com/fullchain.pem;
    ssl_certificate_key /etc/letsencrypt/live/myservers.
domain.com/privkey.pem;
    add_header Strict-Transport-Security "max-
age=31536000";
```

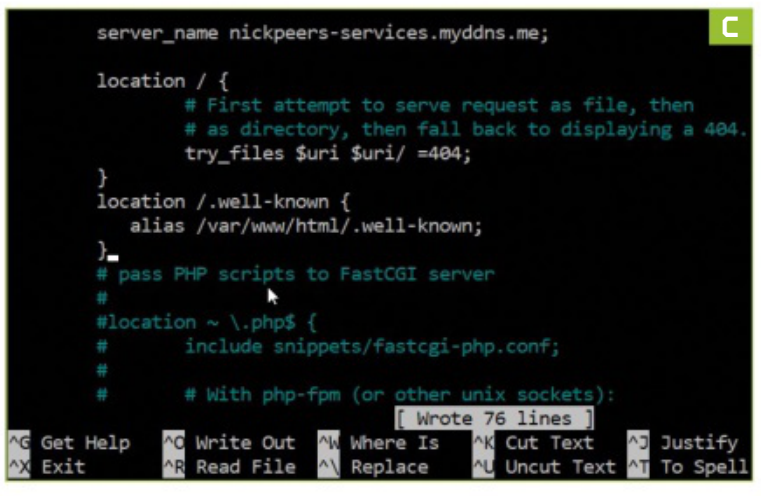
» Save your changes, test them using `sudo nginx -t` before reloading nginx. Now open your browser and you'll find you can no longer access http://myservers.domain.com, but you should now be able to access https://myservers.domain.com. Click the padlock next to the domain name and it should now be verified by Let's Encrypt. Congratulations, you've secured your reverse proxy.

» If you'd like to automatically redirect HTTP (port 80) to HTTPs (port 443), rather than throw up an error, add an additional {server} block to your configuration file beneath the first block:

```
server {
    listen 80;
    listen [::]:80;
    server_name myservers.domain.com;
    return 301 https://$host$request_uri;
}
```

8 YOUR FIRST REDIRECTION

We have got just enough space to set up your first reverse proxy: NextCloud. As we discussed earlier, you need separate {server {location}} blocks for each server you wish to add to your reverse proxy. The "server" block is where you configure the connection parameters—the annotation opposite reveals some of the basic components you need to include: the port you are listening on, plus details about the security you are implementing, along with your SSL certificates. This largely remains unchanged for each server—the main changes are the port you're listening on and what SSL protocols to use, depending on what your server supports. Don't forget to include the "client_max_


C
server_name nickpeers-services.myddns.me;
location / {
# First attempt to serve request as file, then
# as directory, then fall back to displaying a 404.
try_files $uri $uri/ =404;
}
location /.well-known {
alias /var/www/html/.well-known;
}
# pass PHP scripts to FastCGI server
#
#location ~ \.php$ {
include snippets/fastcgi-php.conf;
#
With php-fpm (or other unix sockets):
[Wrote 76 lines]
^G Get Help ^O Write Out ^W Where Is ^K Cut Text ^J Justify
^X Exit ^R Read File ^\ Replace ^U Uncut Text ^T To Spell

CONSTRUCT YOUR SERVER{} BLOCK

```
server {
        listen 32770 ssl http2; (1)

        server_name nickpeers-services.myddns.me; (2)

    (3) ssl_protocols TLSv1.2 TLSv1.3;

        access_log /var/log/nginx/cloud.example.com.access.log;
        error_log /var/log/nginx/cloud.example.com.error.log;

        client_max_body_size 0;
        underscores_in_headers on; (4)

        ssl_certificate /etc/letsencrypt/live/nickpeers-services.myddns.me/fullchain.pem;
        ssl_certificate_key /etc/letsencrypt/li(5)/nickpeers-services.myddns.me/privkey.pem;

        ssl_trusted_certificate /etc/letsencrypt/live/nickpeers-services.myddns.me/chain.pem;
        ssl_stapling on;
        ssl_stapling_verify (6);
        resolver 8.8.4.4 8.8.8.8;

        add_header Strict-Transport-Security "max-age=31536000";
```

1. ENTER LISTENING PORT
This section defines which port your reverse proxy is listening on—plus what protocols it's listening for: typically SSL and HTTP2.

2. DEFINE TRUSTED SERVER
Enter your domain name next to the "server_name" component. If you planned to use multiple subdomains (such as nextcloud.domain.com, bitwarden.domain.com, and so on), you could use this to redirect each one to the correct server.

3. HARDEN SECURITY
The "ssl_protocols" flag enables you to ensure only specific cryptographic protocols can access your servers. Add TLSv1.0 and TLSv1.1 only if your server doesn't support the minimum recommended version (TLSv1.2).

4. OPTIONAL ADD-ONS
Not all server commands are security-related. These two commands help ensure your reverse proxy communicates correctly with the NextCloud server in step 8, below.

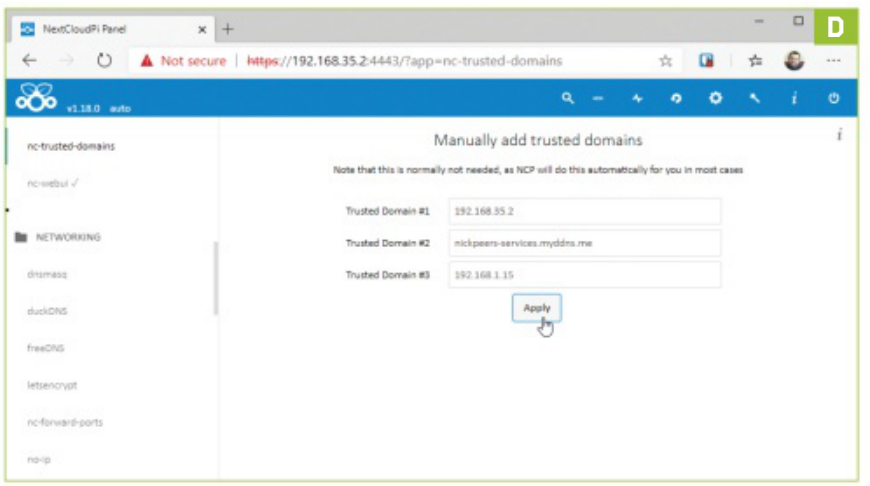
5. SSL CERTIFICATE
This section is crucial—it needs to be present in each {server} block to provide the location of your Let's Encrypt certificate files to validate any external connection.

6. FURTHER SECURITY
These final lines provide additional security: OCSP scaling (ssl_trusted_certificate through to resolver) and HSTS, which forces all communication with the server through a web browser to be performed using HTTPS.

body" and "underscores_in_headers" lines for your NextCloud server's benefit.

» The {location} block determines where the redirection goes. It can be almost as complex as the {server} block, but in the case of NextCloud, it's mercifully simple, comprising just a single line of code:

```
location / {
    proxy_pass https://192.168.x.y:32770;
    }
```



» Substitute "https://192.168.x.y:32770" with your NextCloud server's internal IP address and the port number you're using to communicate with it securely. Save, test, and restart nginix, as outlined in step 5.

» If you followed our guide to setting up NextCloudPi in our November issue, you'll also need to log into the NextCloudPi admin panel (https://192.168.x.y:4443) and add your subdomain or DDNS domain to "nc-trusted-domains" under "Config." Now go to "nc-forward-ports" under "Networking," and change the port for HTTPS from 443 to your chosen port [**Image D**]. Ignore any references to DDNS providers—everything is handled by your reverse proxy.

» All you need to do now is add a new rule to your router's port-forwarding section to direct traffic from your chosen external port to the equivalent internal port on your reverse proxy's IP address, and you're ready to connect remotely, both through your web browser and any client apps you have. Congratulations, you've got your first server up and running. We'll look at more configurations next issue, or you can Google the name of your desired server and "nginx" to track down specific instructions and help for other setups.

Ditch Your Microsoft Account on Win 10

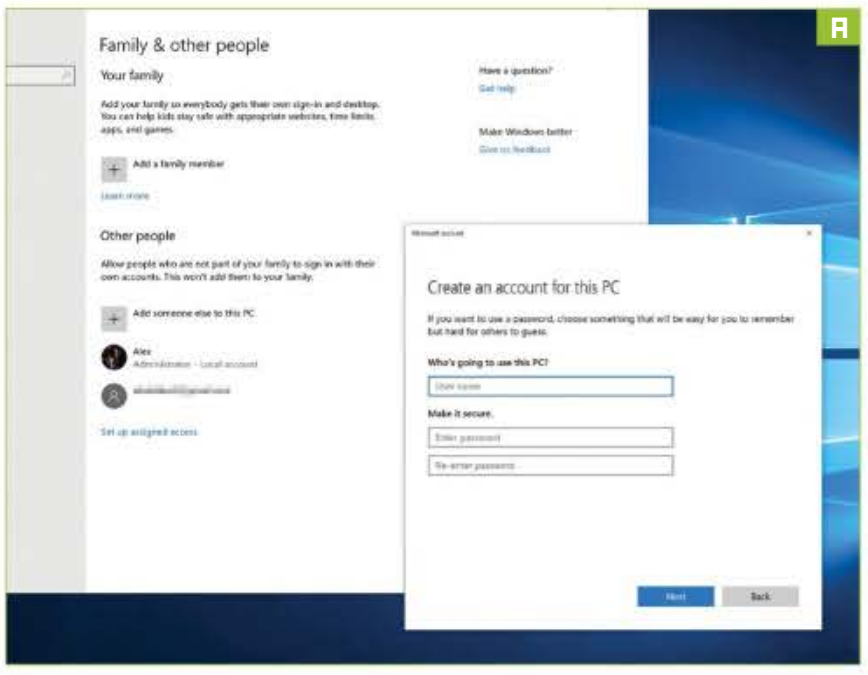
YOU'LL NEED THIS

WINDOWS 10
And the desire to eschew a Microsoft account in favor of a local account.

WHEN YOU FIRST CREATE AN ACCOUNT ON WINDOWS 10, Microsoft would prefer you to use an online Microsoft account that you can use to access all its other services, such as Mixer, Outlook, Skype, and more. But there may be times when you don't want to use this account and would prefer to keep everything on your computer. In times like that, you need to use a local account instead.

This has a couple of benefits. For one thing, it means you can still get going even if you don't already have a Microsoft account—particularly useful if you're setting the account up for someone else and don't know their Microsoft account details. As well as that, there's also the privacy side, because a local account won't sync anything to Microsoft's servers, instead keeping everything on your local machine. And because your Microsoft account uses the same password as your email, if you let someone log in to your PC, they would then have access to your full Microsoft account—not good.

So, there are plenty of reasons to opt for a local account instead of a Microsoft one. Now let's get started and set one up. **–ALEX BLAKE**


A
Family & other people
Your family
Add your family so everybody gets their own sign-in and desktop. You can help kids stay safe with appropriate websites, time limits, apps, and games.
Add a family member
Other people
Allow people who are not part of your family to sign in with their own accounts. This won't add them to your family.
Add someone else to this PC
Alex
Administrator · Local account
Set up assigned access
Have a question?
Get help
Make Windows better
Give us feedback
Create an account for this PC
If you want to use a password, choose something that will be easy for you to remember but hard for others to guess.
Who's going to use this PC?
User name
Make it secure.
Enter password
Re-enter password
Next
Back

1 CREATE A NEW LOCAL USER ACCOUNT

If all you need to do is create a new, separate local account (whether it's for yourself or for someone else), and you've already set up Windows 10, the process is easy and straightforward. You don't need to know their details or have them present to do it, either.

›› First, click the Start menu icon, then click the Settings cog. Once the Settings app opens, click "Accounts," then click "Family and other people" in the left-hand column. Under the "Other people" header, there is an option to "Add someone else to this PC" [**Image A**]. Click this and a new window opens up, asking you to enter the email or phone number of the person who will use the account. Instead of doing this, click "I don't have this person's sign-in information."

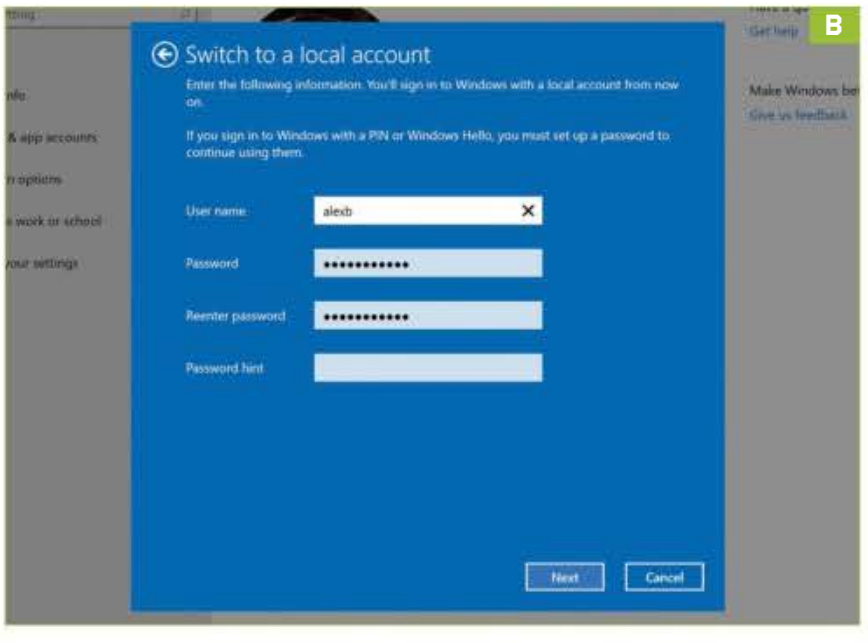
›› This takes you to a page where you can enter the user's email address, password, location, and date of birth. Ignore all of this, and instead click "Add a user without a Microsoft account." On the next page, enter a username and password for the account, and then re-enter the password for security purposes. You can also add three security questions and answers. Once you're finished, click "Next," and the local account is created.

2 CHANGE TO A LOCAL ACCOUNT

If you want to change an existing account from a Microsoft account to a local user account, fear not—it's just as straightforward as it is when you create a new account from scratch. You don't need to worry about being signed in to the account that needs to be changed—if your main account is a Microsoft account, you can change it to a local account without needing to log out or create another account first.

›› To get started, open up the Settings app from the "Start" menu. From here, click "Accounts," then click "Your info" in the left-hand column. Underneath the text reading "Manage my Microsoft account" you should see "Sign in with a local account instead." Click this.

›› A new window opens, so enter your current login password, then click "Next." You are then able to enter a new account name, a password (which you also need to re-enter), plus a password hint [**Image B**]. Once you've done that, click "Sign out and finish," then sign back in again once you have the opportunity. Your account is now configured as a local user account rather than a Microsoft account.


B
Switch to a local account
Enter the following information. You'll sign in to Windows with a local account from now on.
If you sign in to Windows with a PIN or Windows Hello, you must set up a password to continue using them.
User name
alexb
Password
Reenter password
Password hint
Next
Cancel
Get help
Make Windows better
Give us feedback

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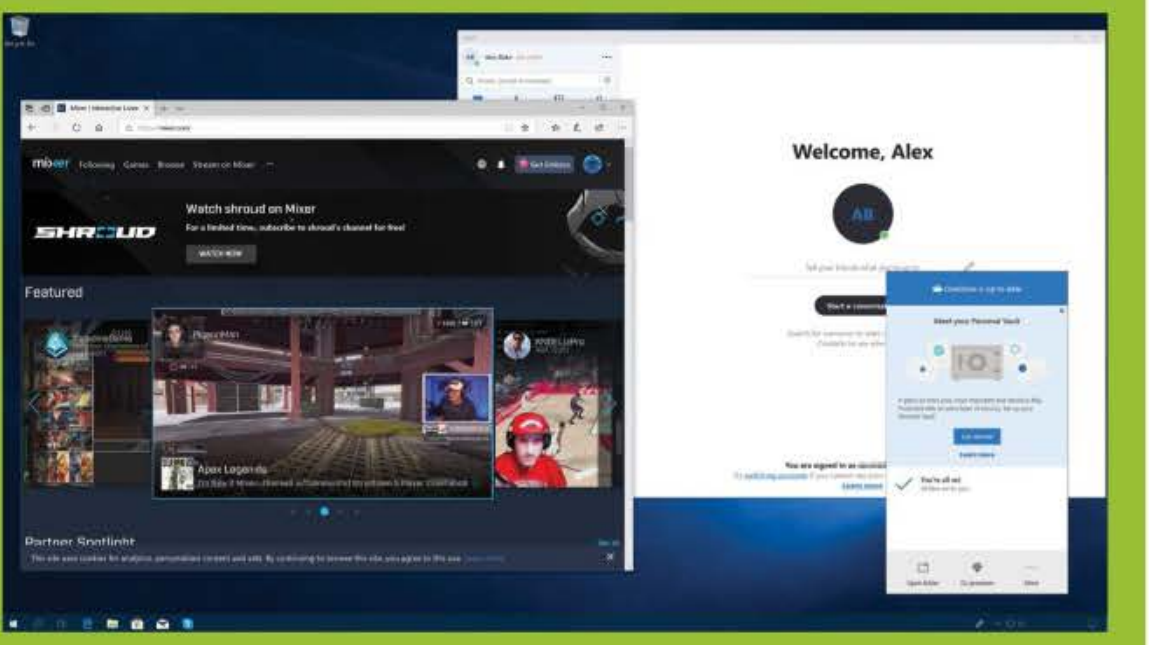
SHOULD YOU EVER USE A MICROSOFT ACCOUNT?

To be fair to Microsoft, using a Microsoft account does come with some benefits. These days, Microsoft runs a whole host of services, and all of these can be accessed using your Microsoft account. For example, you could use your account to log in to Skype, Mixer, Xbox, and more on any device, and your settings will be the same. It also helps improve Cortana, and gives you access to Windows Store apps.

You can also sync things such as your Windows settings, OneDrive files, and photos from your phone between devices, so that when you log in to your Windows tablet, for example, all these files are easily accessible.

But as we outlined in the introduction, there are plenty of reasons why you might not want to use a Microsoft account, particularly when it comes to privacy and security. Just be aware that if you forgo an account, you won't get any of the benefits discussed above.

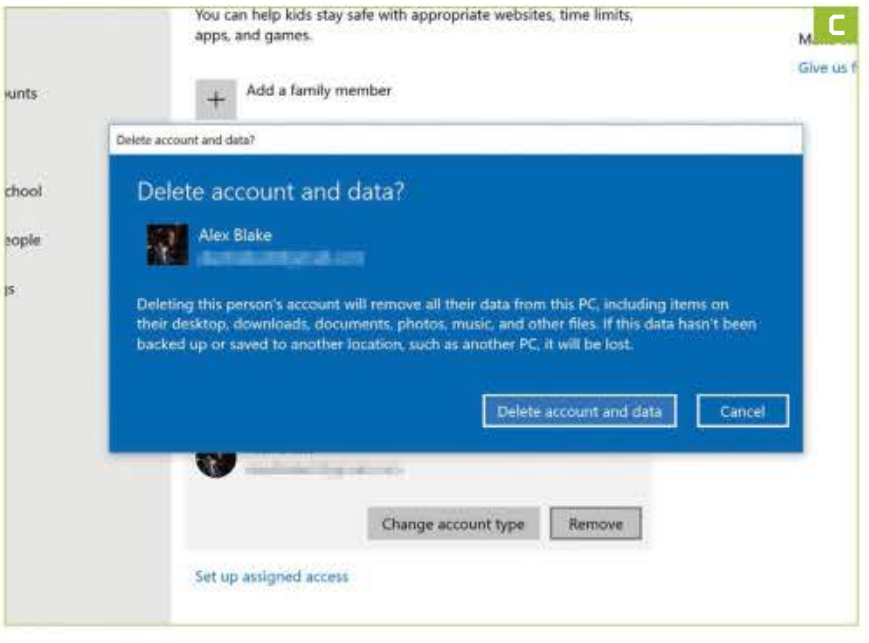


3 LOG IN WITH A LOCAL ACCOUNT ON SETUP

Things are different—and a bit trickier—if you're in the process of installing Windows 10 and haven't yet created any user accounts (Microsoft or local). That's because Microsoft tries extremely hard to push you away from setting up a local user account and toward using a Microsoft account instead. It is possible to resist its unrelenting prodding and create a local user account, but it involves a little work.

›› First off, turn off your Internet connection before creating either a Microsoft or local user account. Then, during the setup process, when you're prompted to connect to the Internet over Wi-Fi or Ethernet, click "I don't have Internet" in the bottom-left corner. This takes you to a splash page where Microsoft extols the virtues of connecting Windows 10 to the Internet; ignore this, and instead click "Continue with limited setup."

›› Alternatively, when you reach the "Sign in with Microsoft" page, click "Domain join instead" in the bottom-left corner. Despite the confusingly obscure name, this actually takes you to a page where you can set up a local user account. It seems Microsoft, in its infinite wisdom, decided to make this as unclear as possible in order to unsubtly guide you toward creating a Microsoft account.


C
You can help kids stay safe with appropriate websites, time limits, apps, and games.
Add a family member
Delete account and data?
Delete account and data?
Alex Blake
Deleting this person's account will remove all their data from this PC, including items on their desktop, downloads, documents, photos, music, and other files. If this data hasn't been backed up or saved to another location, such as another PC, it will be lost.
Delete account and data
Cancel
Change account type
Remove
Set up assigned access

›› Note that setting up a local user account this way requires the 1903 Windows 10 update from Microsoft. Previous versions made it much harder to create a local user account when setting up Windows 10, but if you want to install the operating system today, the latest version should work with the process above.

4 REMOVE A MICROSOFT ACCOUNT

Fortunately, removing a Microsoft account from your PC is quick and simple, and involves no trickery and clever tactics, unlike the previous step. As before, open the Settings app from the "Start" menu, then click "Accounts." In the left-hand column, click "Email & app accounts."

›› On this page, there's a section titled "Accounts used by other apps," which lists all of your currently active Microsoft accounts that are connected to your PC. Click the account you want to delete from your PC, then click "Remove." If that account has previously signed in, you will be asked if you want to delete the account and all of its data—if you click "Delete account and data" [**Image C**], that account's downloads, documents, desktop files, photos, music, and more will be removed from your PC. If it hasn't signed in, you'll see a different warning box; click "Yes." Note that this doesn't delete the Microsoft account itself (you'll still be able to use it to sign in on Microsoft's websites, for example), it just removes it from your computer.

›› Alternatively, you can remove a Microsoft account through the Control Panel app. In the Windows 10 search box, type "Control Panel" and click the top result. Click "User Accounts," then "Remove user accounts." This now lists all of the accounts set up on your PC. Click the account that you want to remove, then click "Delete the account." You get a warning that all of that account's files will be removed; click "Delete Files," then "Delete Account."

›› That's all there is to it. Once the Microsoft account has been removed from your PC, you'll be able to use a local user account to sign in instead.

Machine of the Month: Atari ST

›› The all-American Atari ST: Used by approximately three Americans and a billion French people.

YOU'LL NEED THIS

HATARI
Atari ST emulator that supports a number of host platforms—get it from https://hatari.tuxfamily.org.

STEEM SSE
If a particular game doesn't run under Hatari, this is worth trying instead: https://sourceforge.net/projects/steemsse.

REGARDED BY MANY as the first proper 16-bit computer, the Atari ST was a powerhouse for its era and price. If you don't associate this kind of serious product with Atari, fair enough. This is not the same company that put Pacman into American living rooms—this was a new era led by the most bullish man in the business: Commodore founder Jack Tramiel.

Tramiel spent the early '80s aggressively expanding Commodore's market share, undercutting the competition. The results led to the Commodore 64 becoming the best selling computer of all time, but Tramiel's brutal methods were unsustainable and burned too many bridges. Commodore was sick of Jack, and Jack was sick of Commodore. Tramiel left in a huff in January 1984.

Meanwhile, Atari was reeling from America's video game crash of 1983, bleeding a million dollars a day by 1984. Parent company Warner wanted to cut its losses, and Tramiel saw an opportunity, buying Atari's consumer division in July 1984. He kicked the company into shape in his usual aggressive style, firing almost everyone, and bringing a team of engineers snatched from Commodore to create a new machine. With Atari, Tramiel had an established name through which he could sell products and focus on developing a new computer. –JOHN KNIGHT

1 DEVELOPMENT

Tramiel had specific goals for his new machine: It would be 16-bit, powerful, cheap, and dramatically undercut Apple and IBM on price, while sticking it to Commodore.

›› Commodore 64 developer Shiraz Shivji was put in charge of the machine's design. For a CPU, National Semiconductor's NS32000 chipset was initially considered, but after witnessing disappointing performance, the team went with the Motorola 68000 instead.

›› Weirdly, pre-Tramiel Atari had already flirted with Motorola's 68000, with some key engineers wanting to make a 68000-based machine, but management wasn't interested. These engineers left Atari to start their own company, Amiga, and the computer Commodore would later buy and sell as its flagship model. In a strange twist of fate, Atari's engineers ended up working for Commodore, and Commodore's engineers moved to Atari.

›› For an OS, Atari rejected Microsoft's unfinished Windows 1.0 in favor of Digital Research's GEM (Graphical Environment Manager). After combining it with its underlying DOS, the environment was dubbed TOS (The Operating System). This simple and highly usable environment was similar to the Macintosh and often dubbed the "Jackintosh" after Tramiel.

›› While the team had originally planned to use a custom sound chip, time ran out, and Atari had to settle on a bargain-bucket Yamaha YM2149 chipset. To make up for it, Atari installed factory-standard MIDI ports, something that would turn out to be a 75-cent stroke of genius.

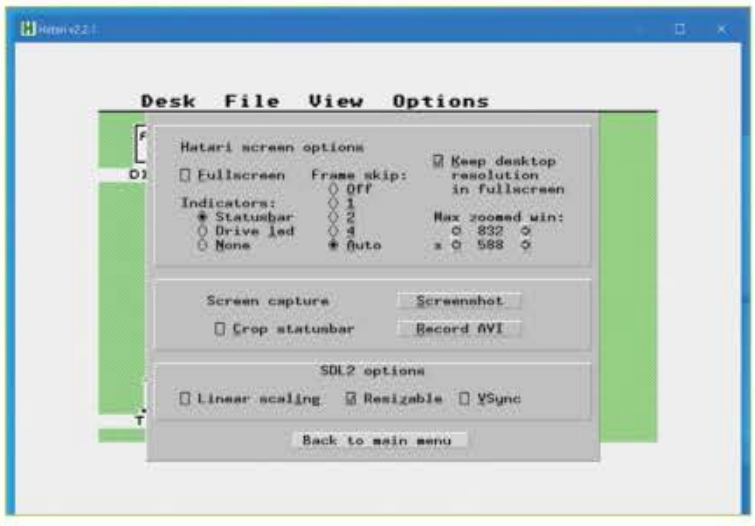
2 LAUNCH

Released in June 1985, the Atari ST packed a Motorola 68000 CPU running at 8MHz, laid claim to 512K of RAM, and had a proper mouse-driven GUI. Arriving a month sooner than the Amiga, prices were $800 for a monochrome version or $1,000 for color, around $500 cheaper than an equivalent Amiga.

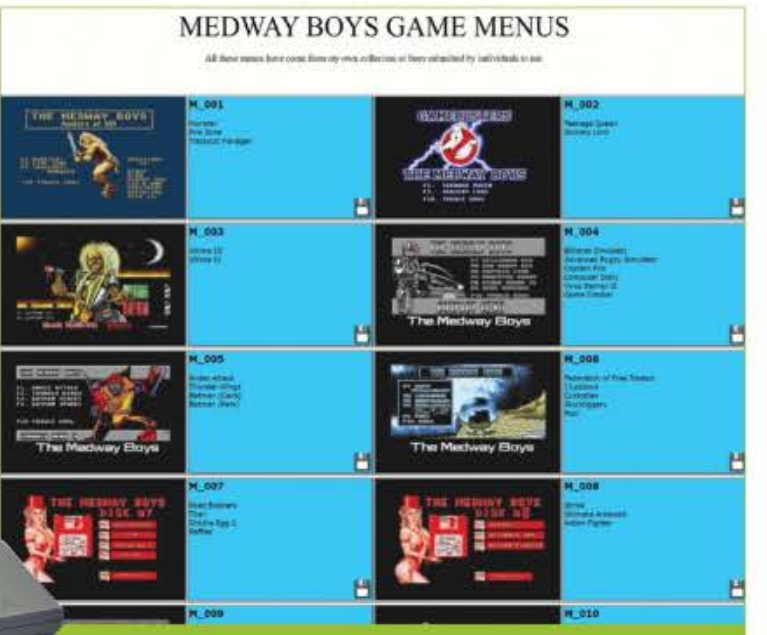
›› TOS was a hit with consumers. Atari's high-res monochrome mode was popular with business users, and being able to buy an Atari ST with a printer and hard drive for less money than a single IBM printer made it popular with artists and publishers, too. Furthermore, it could use MS-DOS formatted floppies, and even emulate Mac software—faster than a real Mac.

›› The ST became an instant hit with musicians as well. Despite the cheap sound chip, when plugged into external MIDI, the Atari ST truly shines, with better latency than a lot of professional equipment. Programs such as Cubase started life on the ST, and its MIDI functionality is still used today by a number of high-profile musicians.

›› The ST had rapidly turned Atari's fortunes around, although it was only a niche player in the US, where IBM compatibles were dominant. The ST was far more popular in Europe (especially France), where it accounted for 75 percent of total sales—IBM machines were seen as too expensive, and TV-based micros were still popular. If you want a real Atari ST, buy a European



›› Hit F12 in Hatari to bring up the main settings screen. From here, you can switch to high-res monochrome mode.



›› Atari's TOS interface may look horrible now, but there's a clean and simple elegance to these old operating systems.

model, because the PAL library utterly dwarfs the number of NTSC titles.

›› The gaming market was strong during its first years. Classics include 1987's first-person RPG *Dungeon Master;* Peter Molyneux's pioneering god game, *Populous* (1990); and 1993's tactical shooter, *Cannon Fodder.* However, support began to wane when Commodore introduced the cost-reduced Amiga 500, which had better graphics and sound than the ST, ultimately swallowing its gaming market.

›› Over the years, it released better machines to rival the Amiga, but neither company could compete with the PC market, which was growing cheaper by the day. Atari produced some 32-bit machines in the early '90s, but stopped making computers in 1993 in favor of a shift to consoles, and the ill-fated Atari Jaguar.

3 HOW DO I EMULATE IT?

The first thing you should know about is EmuTOS (https://emutos.sourceforge.io/en). Most ST emulators require a system ROM (TOS) to function. EmuTOS is a free, open-source re-implementation of TOS that can run on original hardware (even some Amigas), or be used by emulators as a replacement system. It will suffice for most uses, but programs requiring obscure functionality may need an original system ROM.

›› The two most popular emulators are Hatari and Steem SSE. Hatari is probably the best choice, and it offers versions for Windows, Mac, and Linux. (Note that on the PC you may need to run it as administrator.) Once loaded, you should hit F12 to configure a few settings, including where the two floppy drives point to, which will be any disk images you download.

›› Hatari running EmuTOS: Not everything is going to work with this setup, but simpler apps should be good.

›› The Linux version in system repositories will probably start with an error about the TOS file—licensing restrictions mean that a system ROM is unlikely to be included. You therefore need to specify a TOS file in the application's ROM menu, whether it be EmuTOS or a proprietary ROM image. Windows builds from the website come pre-loaded with EmuTOS, although you can use a proprietary ROM if you prefer (https://hatari.tuxfamily.org).

›› Steem (now Steem SSE) used to support Windows and Linux (https://sourceforge.net/projects/steemsse); newer versions only support Windows, but it runs well under Wine. Steem SSE requires a ROM image. We prefer Hatari to Steem, but if something doesn't work under one emulator, it's worth trying the other.

›› For lazy gamers RetroArch has a core based on Hatari, under "Load Core → Download a Core."

WHERE CAN I FIND SOFTWARE?

The obvious place to find games is via general ROM sites, but they are fraught with legal issues. These sites can also be a great source for system ROMs (TOS images in the ST's case), and switching between system ROMs can help get pesky programs running, but copyright issues still apply.

For visual demos and non-gaming apps, you usually need to look elsewhere. Archive.org has a few gems you can play with, and you don't have to sort through legally suspect ROM sites. However, the easiest way to find legal software of any sort is through magazine coverdisk archives, which usually mix gaming and utilities. We had most luck with Exxos's archive (www.exxoshost.co.uk/atari), which has a collection of disks from *ST Format* (a Future Publishing magazine that ran from 1989 to 1996). The collection is archived in .MSA format, which is easy to load, and compatible with Hatari.

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Master Dropbox in Windows 10

YOU'LL NEED THIS

DROPBOX
Sign up for an account at www.dropbox.com.

DROPBOX IS AN APP THAT, at its heart, synchronizes a folder on your PC with other computers—the same files are available everywhere. You can also access them via the web on any device, although the files aren't actually stored on your device, unless you choose to download them. In many ways, it works very similarly to Microsoft's OneDrive.

Dropbox isn't really meant as a cold storage system—its plans for lots of storage are rather expensive, and it's recently been targeting business users over consumers—but for managing the stuff you're working on right now, it's unparalleled. We often work across multiple devices and use it as the main place to store our files, instead of our "Documents" folder. What's more, you can share files with other people, and easily find things, too. Dropbox is free for 2GB of storage—if you need anything beyond that, you have to pay. **–DAN GRABHAM**

1 DOWNLOAD THE APP

Go to www.dropbox.com to download and install the desktop app. There is also an app in the Windows Store, but it's more like the mobile version of the app, and it doesn't do the file synchronization we want to show here. You may be prompted to buy a Dropbox plan [**Image A**], but you don't need to do that.

2 SIGN INTO THE APP

You need to sign into the app to link it to a Dropbox account. Don't have a Dropbox account? Then you can sign up now. You can also use Google to sign in if you have an existing Google account. Creating a Dropbox account is a really simple process and the app won't ask you for extra details it doesn't really need.

3 SELECT FOLDERS

You can either choose to sync everything to your computer from your Dropbox, or use what's called Selective Sync. With this, you choose which Dropbox folders to synchronize with this particular PC [**Image B**]. With new Dropboxes, this won't be a problem, but we're demonstrating this with a nearly full Dropbox to show you how everything works, because it wouldn't be much good if we had no files to explain the process with.

4 SHARE SCREENSHOTS

When you start up Dropbox for the first time, you get a prompt [**Image C**] asking whether you want Dropbox to manage screenshots as you take them—this can be useful because they pop into a "Screenshots" folder in your Dropbox, and sync right away. Similarly, you can ask Dropbox to instantly sync photos from cameras you plug into your Windows PC, and it prompts you about that when you plug one in.

5 THE DROPBOX FOLDER

The key window of Dropbox is the local (on your PC) folder that shows everything that's currently in your Dropbox [**Image D**]. As you can see, Dropbox overlays icons—these blue spinning icons indicate synchronization taking place. A green check mark means that file has been synchronized. Dropbox updates in real time, so if a file is edited somewhere else, the change is reflected right away.

6 SHARE FILES

You can share files from just about anywhere in Dropbox—here's how to share in Windows. Right-click a file, then go to "Share" alongside the Dropbox icon. You'll then see a rather plain window [**Image E**], which enables you to write a message and say where the file is going—just add an email address. You can also share by copying a Dropbox link that you can send in other ways, such as in a text message.

7 THE APP MENU

Finally, we see the Dropbox app! It sits in your notifications area looking like it's doing nothing. In fact, it's keeping an eye on your files and making sure they synchronize. Clicking the Dropbox icon brings up the menu shown opposite [**Image F**]—it shows you all the recently edited and synchronized files, and when they were modified. This menu also shows you any notifications you need.

8 FOR YOU

The "For You" menu seen opposite [**Image G**] looks a little blank, but it'll populate with tailored access to files you use often. In our example, it's showing our "Current Work" folder, which is one of our most-used folders. Note that synchronization is taking place here—you can see the progress at the very bottom of the window, where Dropbox tells you how many files there are left to process.

9 SEARCH FOR ANYTHING

At the top of the app menu is a search bar. As well as names and icons, Dropbox shows you other file information, such as size, and when it was last edited. You can also see where in your Dropbox the file is stored—you might have a "january.xlsx" in a "2019" folder, but also one in "2018" and "2017." The "link" icon gets you a link to the selected file directly from this window.

10 MANAGING FILES

There are stacks of other file management options in the main menu [**Image H**]. Select a recently uploaded bunch of files, and you can unfurl the bundle to see each file. You can share it, get a link, star it for easy retrieval, or open the file. What's more, you can open it in specific apps, so if you want to send an image to Photoshop, you can do that from here.

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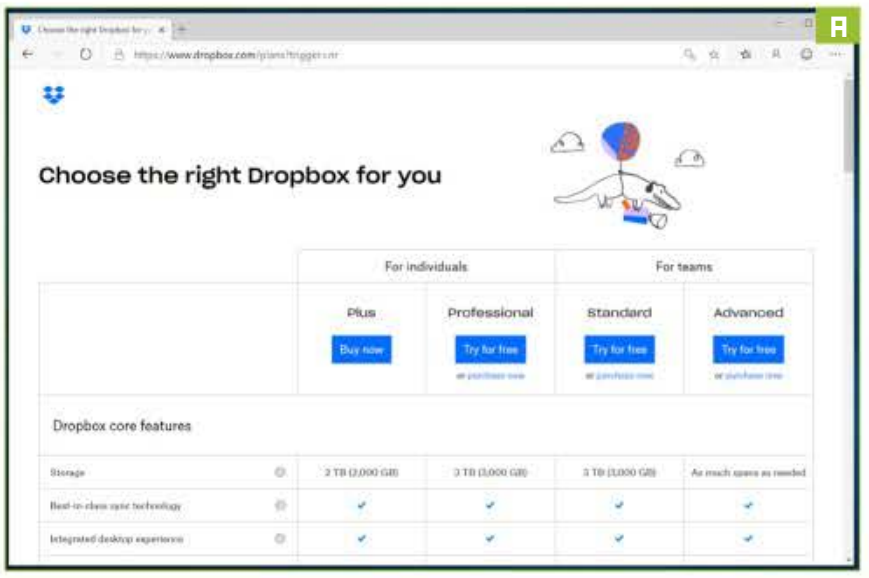
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Choose the right Dropbox for you
For individuals
For teams
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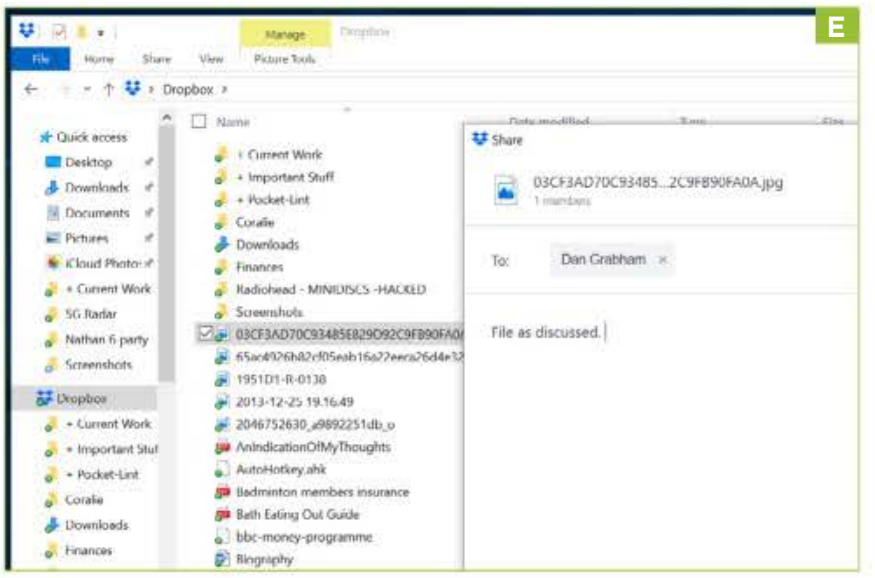
Try for free
Dropbox core features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Dan Grabham
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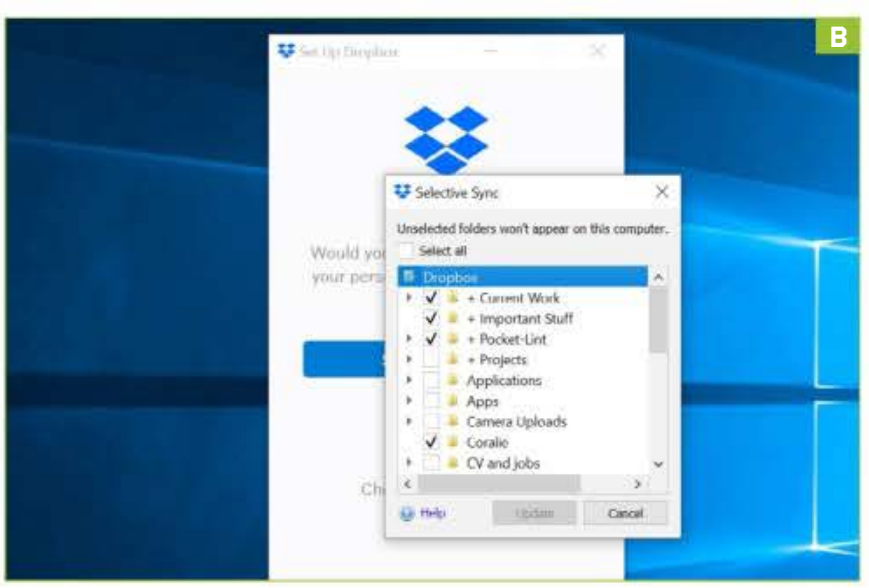
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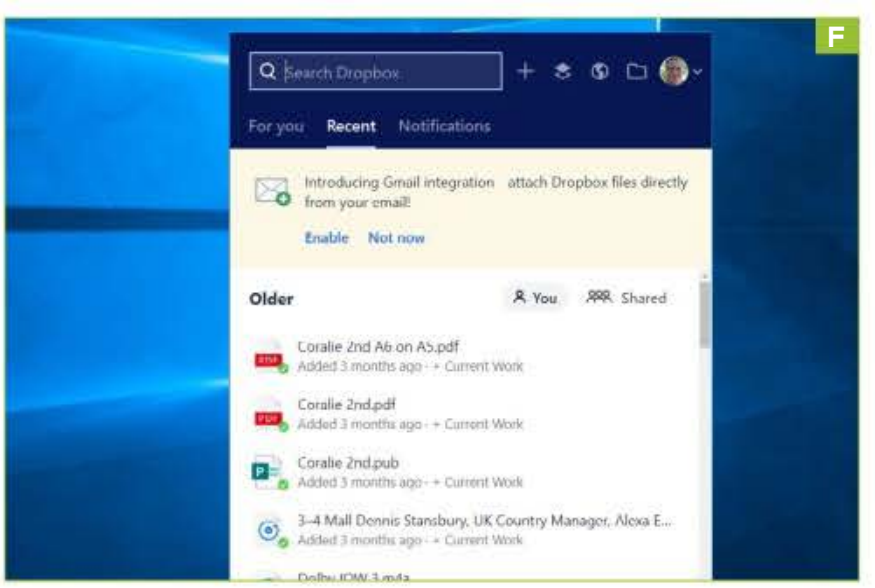
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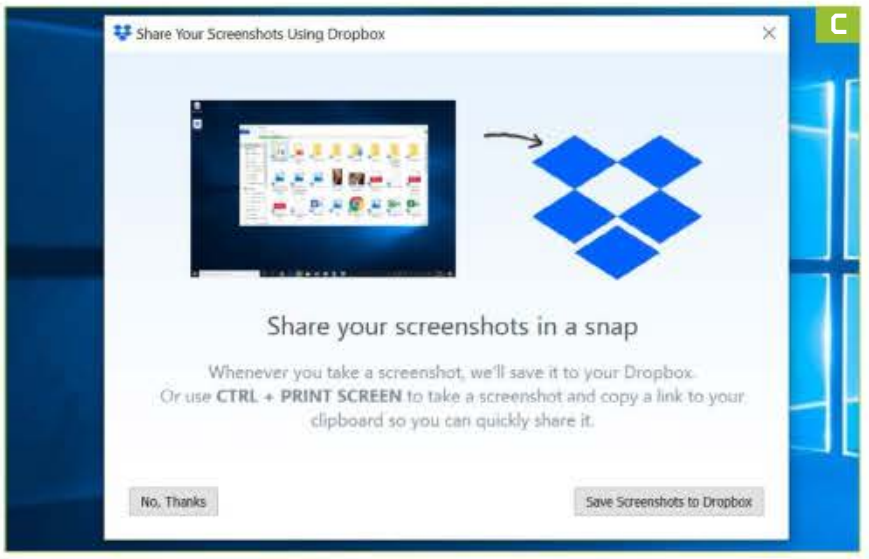
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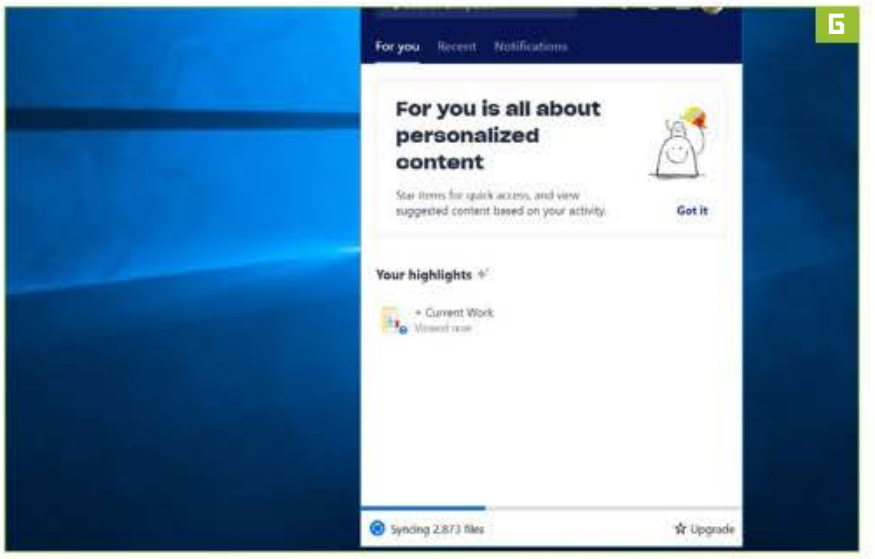
Share Your Screenshots Using Dropbox
Share your screenshots in a snap
Whenever you take a screenshot, we'll save it to your Dropbox.
Or use CTRL + PRINT SCREEN to take a screenshot and copy a link to your clipboard so you can quickly share it.
No, Thanks
Save Screenshots to Dropbox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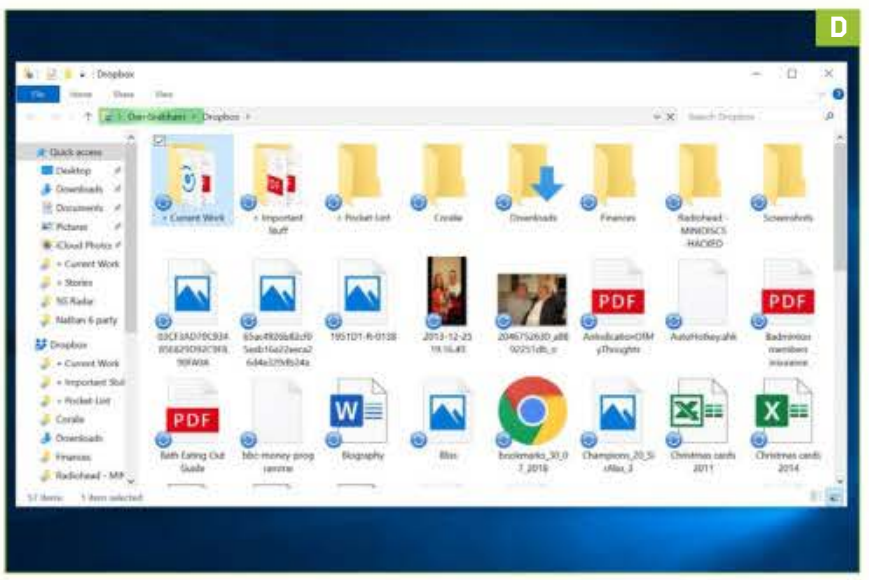
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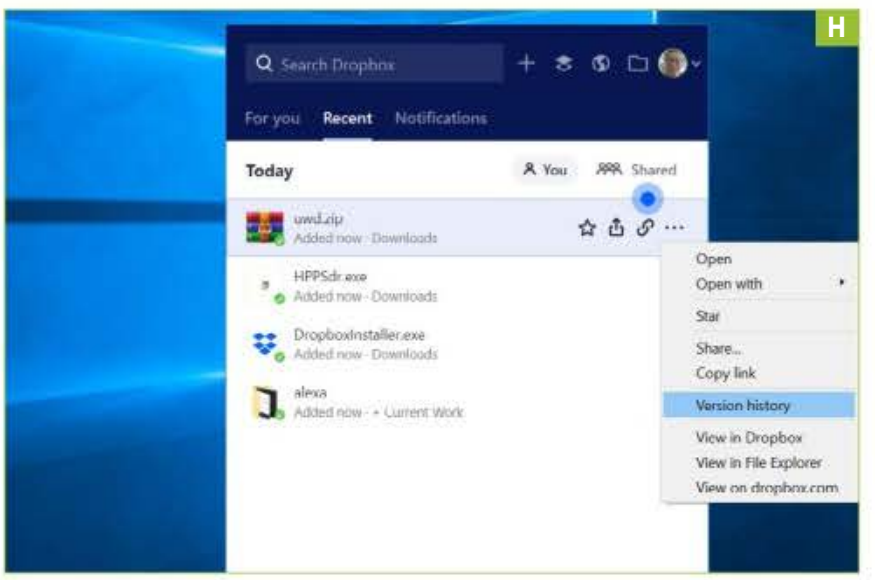
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View in File Explorer
View on dropbox.com

Manage Lists with the To Do App

YOU'LL NEED THIS

MICROSOFT TO DO APP
Install the app from the Microsoft Store.

WHETHER A SIMPLE SHOPPING LIST or the complex steps for a project you are working on, just about everyone can make use of a to-do app. Being able to make a list and check things off as you go is an effective way to keep track of what you're doing, so you can better manage your time. Microsoft has its own to-do app, appropriately named Microsoft To Do. It is free for Windows, Android, iOS, and macOS, as well as online. You can create checklists, so you can check things off as you do them, and cross-platform synchronization means you can access your lists from different devices—such as your computer and your phone.

Microsoft To Do is about more than just simple lists, however. You can also use the app to store notes, create alerts, and manage recurring items—as you will see as we explore this incredibly useful tool. –MARK WYCIŚLIK-WILSON

1 DOWNLOAD AND INSTALL TO DO

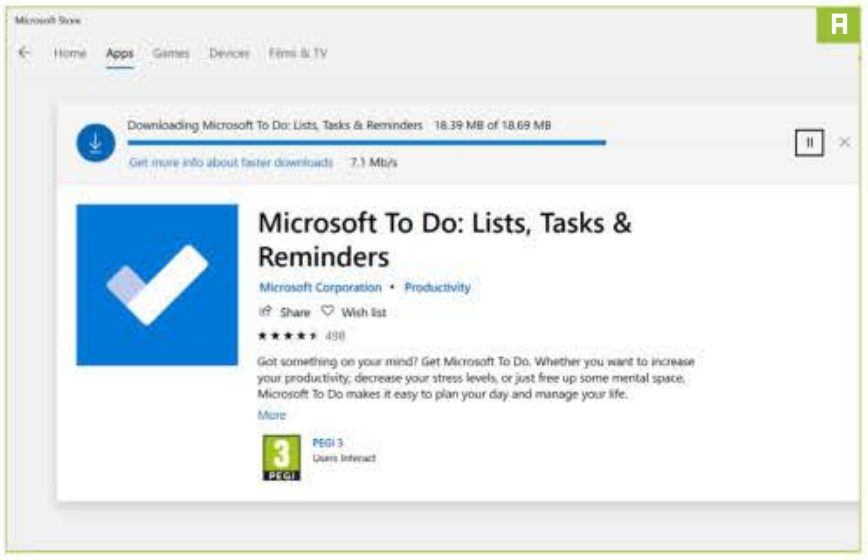
The Microsoft To Do app is available for free download in the Microsoft Store [Image A]. Launch the Store app from the "Start" menu or taskbar shortcut, search for "Microsoft To Do," and click the "Install" button. You should be automatically signed into your Microsoft account the first time you launch the app, but if not, you can do it manually—this helps with synchronization between devices.

2 CREATE LISTS

Lists are at the heart of To Do, and you can create one by clicking "New list" at the bottom of the left-hand panel. Type a name for the list to make it easier to identify when you create more later. Click the "..." button to the upper-right, and you can choose a color theme that not only changes the main background color, but also the text in the list of lists.

3 ADD TASKS TO LISTS

A blank list is of little use, so you need to add items. To Do refers to items on a list as tasks, and you can start building up your list by clicking the "Add task" button at the bottom [Image B]. Add as many items to the list as you need. You can use the star icon to the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Get more info about faster downloads 7.1 Mb/s
Microsoft To Do: Lists, Tasks & Reminders
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Wish list
498
Got something on your mind? Get Microsoft To Do. Whether you want to increase your productivity, decrease your stress levels, or just free up some mental space, Microsoft To Do makes it easy to plan your day and manage your life.
More
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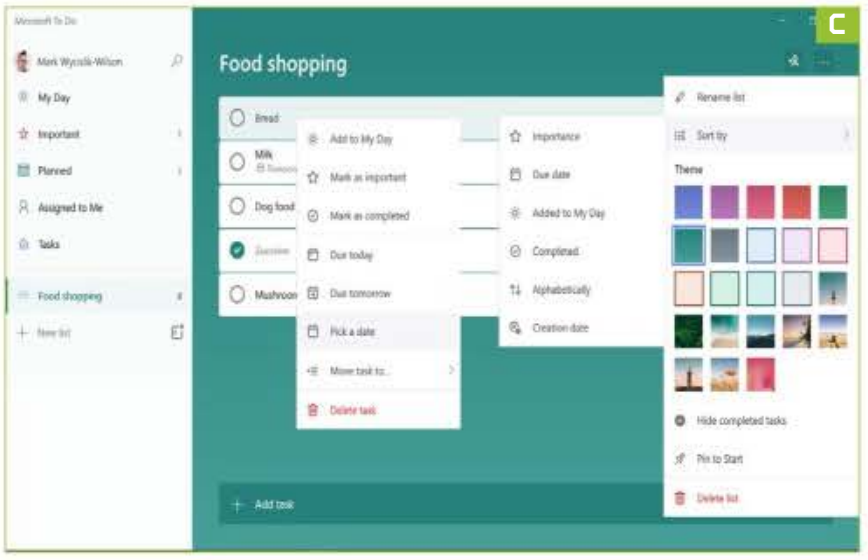
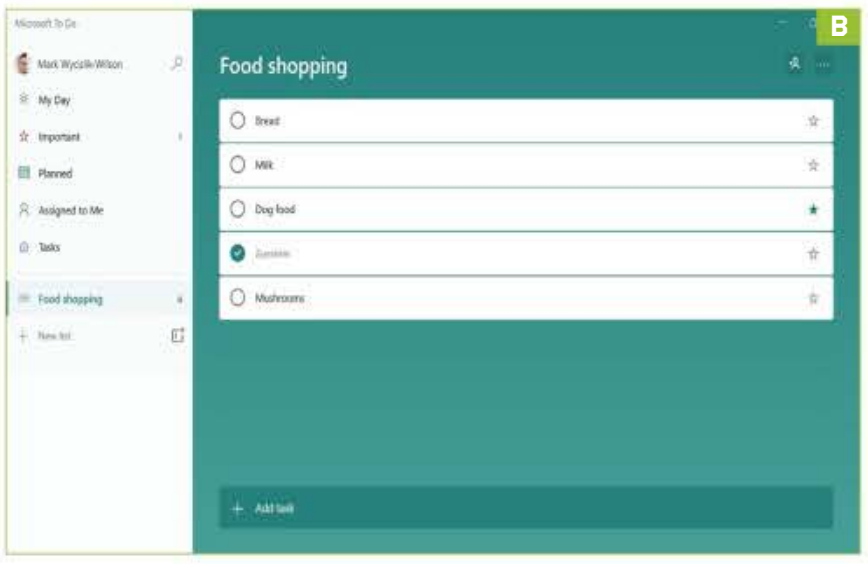
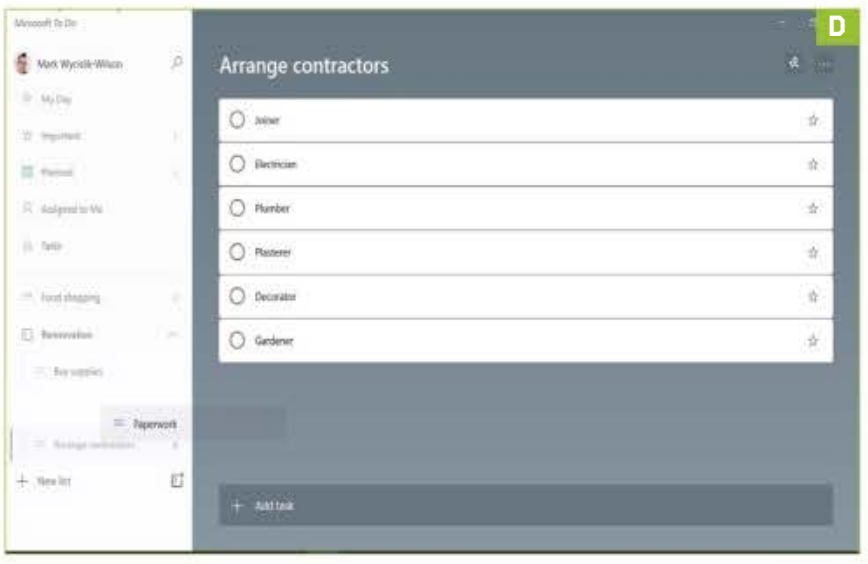
Users Interact







© MICROSOFT

right to mark something as important, and click the checkbox to the left to mark it as complete.

4 OTHER LIST OPTIONS

If you right-click an item on a list, you can do things such as moving it to the "My Day" section for increased visibility, and set a due date. In the "Settings" menu you accessed in Step 2, you can opt to re-order the list based on the due dates assigned to entries, and choose to hide completed items—this is particularly handy when it comes to shopping lists [**Image C**].

5 GROUP LISTS

Sometimes it makes sense to group lists together, perhaps to break a large project down into smaller components, but still keep them linked. It's a great idea for things you may be working on at work, a building project, or an event. Click the button to the right of "New list" to create a new group, which you can then name. You can create and drag new sub-lists into the group [**Image D**].

6 SHARE LISTS

In the case of shopping lists or larger projects, it can be helpful to have collaborators—and To Do enables you to share lists with others. In the upper right-hand corner of a list, next to the "..." settings button, you'll see the "Share list" button. Click it, and you get an invitation link you can send to people [**Image E**]. If they accept, they will be able to not only see, but also edit the list.

7 CREATE TASKS

Tasks are rather more versatile than lists for a number of reasons. Tasks can be made up of multiple steps, and you have the option of attaching files and notes to them—all perfect for larger, more complicated projects. It is also possible to assign reminders to tasks, so you don't miss an important deadline. Click "Tasks" to the left, then click "Add task."

8 ADD TASK STEPS

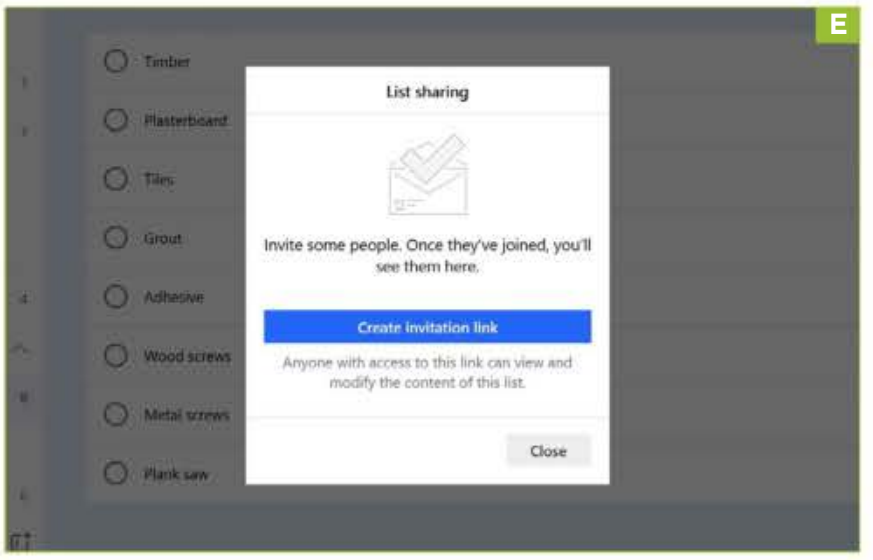
Click the task you have created, and a panel appears with further options. By clicking "Add step" and "Next step" in this panel, you can add sub-tasks to a task, which can be checked off one by one. You'll notice that the main task entry indicates how many steps it has, and how many have been completed [**Image F**]. Tasks can also be customized with colored backgrounds, just like lists.

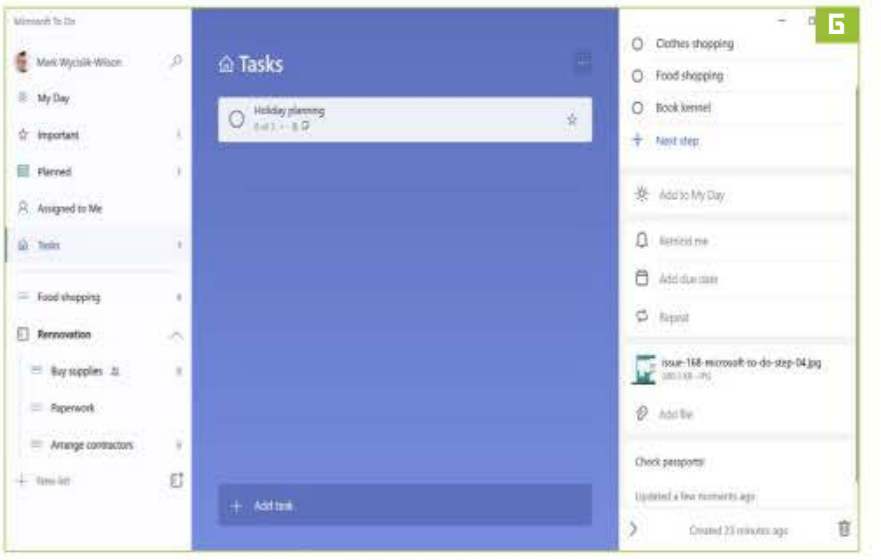
9 REMINDERS AND ATTACHMENTS

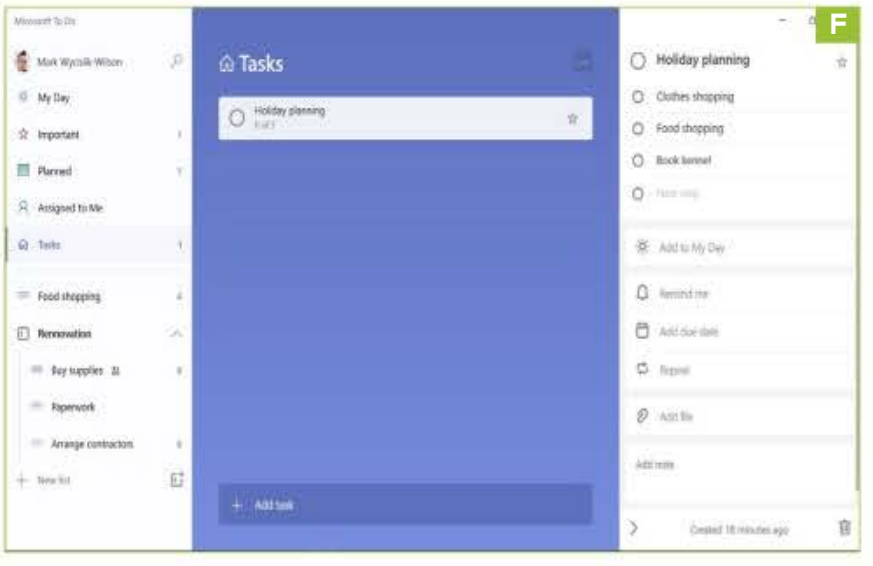
If you need to complete tasks to a deadline, To Do enables you to add a reminder. In the right-hand panel, use the "Remind me" option to add an alert, or just set a due date. You also have the option of making tasks into recurring items. Toward the bottom of the panel, you will find the option to add notes and even attach files that you may need in the course of working on the project [**Image G**].

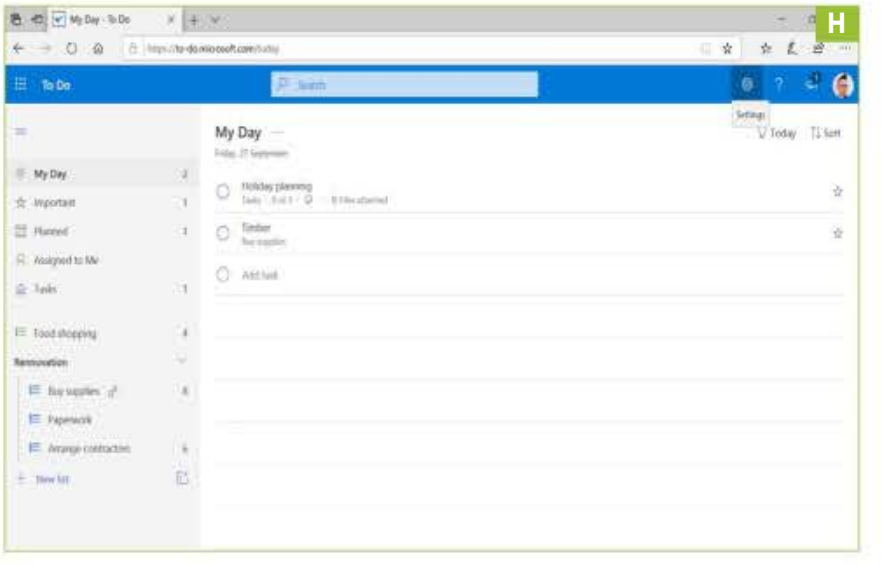
10 TO DO ONLINE AND ON MOBILE

The beauty of To Do is that you can access it from just about anywhere. You set things up on your desktop or laptop, but the To Do website (http://to-do.microsoft.com) is essentially identical to the app [**Image H**]. There are also versions of To Do for Android and iOS, so you can use your smartphone to check your shopping list when you're in the supermarket.









Meet New Features in Photoshop 2020

YOU'LL NEED THIS

CREATIVE CLOUD
Sign up for a subscription at www.adobe.com.

FOR ANYONE WHO SPOTTED THE CREATIVE CLOUD APP chugging and downloading recently, well, it was Photoshop getting a big update. Adobe seems to have dropped the CC moniker, although Creative Cloud is very much still with us. Version 2020 (or 21) of the venerable image-editing app brings a swathe of improvements across the whole face of the app, but stops short of fundamentally changing the look and feel, which has been set since the dark gray background made its appearance several years ago.

Some of the changes are to tools that have been the same since forever—the Brush tool, for instance, can now be rotated with the arrow keys while you're painting, and hitting tilde (~) flips it into an eraser. The Properties panel, much unloved, has been revitalized with shortcuts to useful tools, depending on what you've got selected. Then there's the Sensei cloud tech of which Adobe is so proud, further integrated into Photoshop with the new Object Selection tool.

So, while it's not a breathtaking reinvention of the app, the latest updates are sure to calm the troubled brows of subscribers, who get an updated app without having to fork out over $600, like in the old days. **–IAN EVENDEN**

1 OBJECT SELECTION

This is probably the headline new feature, because it's a bit like magic. Users of Photoshop Elements 2019 will already be familiar with it, because—bafflingly—it appeared in CC's cut-down little brother a full year before coming to the main suite. Perhaps it was some sort of test. Whatever, it's here now, and mostly works. If there's an object clearly defined against a clear background, it's able to select it just fine. If the dividing line isn't clear, or if the object and background are the same color, it can have difficulty. Even so, it's usually enough to get you straight to the Select and Mask stage, perhaps filling in a few gaps first with the Quick Selection brush, rather than fiddling about making a fully manual selection.

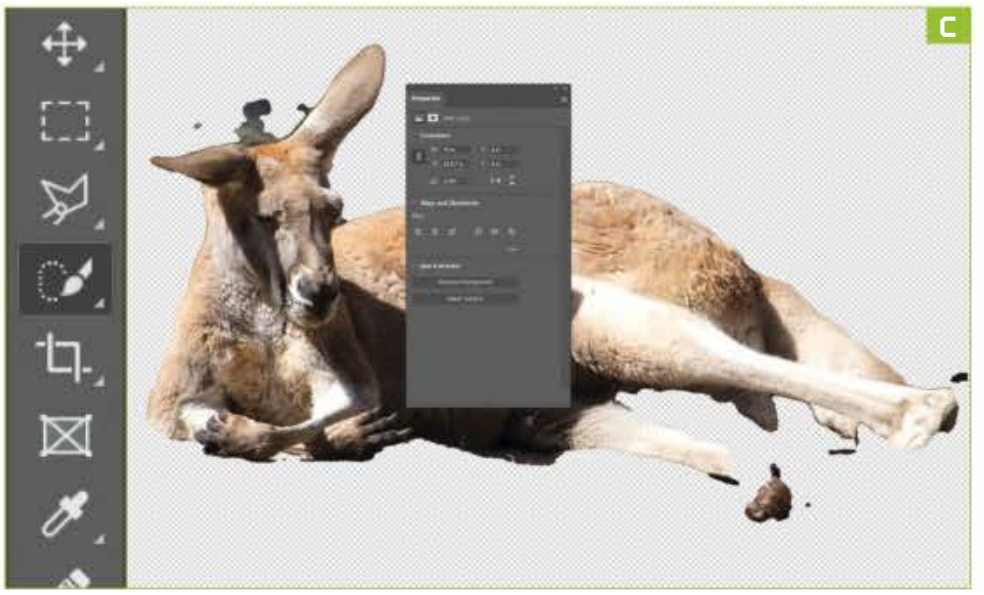
2 USING OBJECT SELECTION

You'll find the Object Selection tool buried in the toolbar along with the rest of the selection tools. It looks like a square with an arrow beside it. To use it, drag a rectangle around the object you want to select, and let go. The app does the rest. There's a couple of options, however. One is that, instead of dragging a rectangle, you can use a version of the Polygonal Lasso to more precisely outline the object you want to be selected. And when it works, it works very well, as you can see on our picture of an orca [**Image A**]. The selection outline has tightly wrapped to the division between whale and sea, even though this isn't the sharpest photo, leaving us just one area below the fin to touch up. Our other image, of the kangaroo, however, fared less well. Even using the lasso wasn't enough to get the program to select the lower back leg, a consequence of the animal being a very similar color to its background [**Image B**]. Using Photoshop's existing Select Subject functionality caught much of the lower leg, but also added the rock behind the kangaroo's head.

3 IMPROVED PROPERTIES

Elsewhere, the Properties panel has been shown a little love. If you're working on a single Background layer, you now get options to change the size of your canvas, including its bit depth and color mode—it's now a fast way to change an image to grayscale without bothering the "Image" menu. There are also shortcuts to show and hide rulers, guides, and the grid, and Quick

© ADOBE



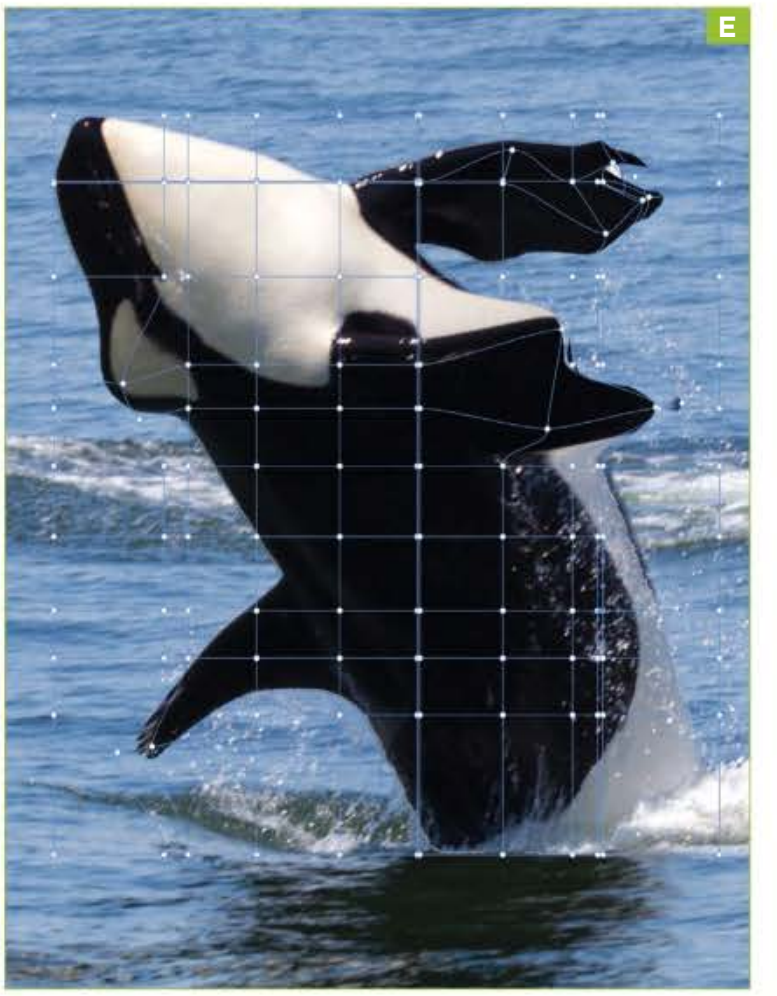
Actions including Crop and Image Size. Select a layer, and you have access to Transform, Align, and Distribute controls, again without having to seek them out in their usual hiding place, and the superb new Remove Background, a riff on Object Selection that selects the subject and separates it and its background into a Layer Mask [**Image C**]. It suffers from the same problems as Object Selection, but it's nice to see it included. Selecting a type is particularly well supported, with full formatting support on the Properties panel, along with the ability to convert type to frames or shapes. Selecting a Smart Object brings up a different set of options, too, including the new "Convert to Layers" option.

4 CONVERT TO LAYERS

You can now convert a Smart Object to plain old pixel layers. You could do this before, by opening up a Smart Object and dragging the layers within back to the Layers palette, but now you can do it with a click from the Properties panel. Multiple layers within the Smart Object become a layer group, and you can choose to retain or discard Smart Filters or applied transformations.

5 CONTENT-AWARE FILL

The magic object eraser gets some extra options in the form of its own panel and preview window, still triggered from the "Edit" menu. Now you have control over the sampling area used to generate the fill, and can tint it any color, so you know where you're working [**Image D**]. There's also a couple of extra modes in addition to the Auto setting, so you can choose a plain rectangular sample, or draw your own with a brush. There's also the option to output to your current layer, a new one, or create a duplicate to keep both versions.



6 EVERYTHING ELSE

There are also changes to the Warp tool, enabling you to place control points anywhere with Alt-click [**Image E**]. If you've got a selection outline in place, this warps, too. Free Transform gets a nudge in the right direction by no longer requiring you to hold Shift all the time—it's now constrained by default. You can switch back to the old behavior in Preferences if your muscle memory complains. The Lens Blur filter now has a "Set Focal Point" button for working with depth-mapped images, and Presets—the gradients and patterns that have been the same for 20 years—get a shake up with new content and new ways of working. Panels such as Swatches and Styles have also been reworked, making the switching of colors in a composition much easier.

CLOUDY OUTLOOK

TypeKit seems to be a thing of the past now, because all 17,000 Adobe Fonts are included with a Creative Cloud plan (including the Photography plan), and are easily identified in the font menu by the new Creative Cloud icon to the right of the font name. All fonts are cleared for personal and commercial use, and there are no longer any limits on how many you can activate and use at one time. Seventeen thousand is a lot, so click the icon to the right of "More from Adobe Fonts" to explore and activate additional fonts as you need them.

There's also a new "Cloud Documents" tab when opening a file, which enables file transfer with the new iPad version of Photoshop.

BUILD IT

CHRISTIAN GUYTON, STAFF WRITER

Getting VR-Ready

This month, we're putting together a powerful system for virtual-reality experiences

LENGTH OF TIME: **2-3 HOURS**

LEVEL OF DIFFICULTY: **MEDIUM**

THE CONCEPT

YOU MIGHT HAVE seen this coming. There's been a lot of talk about virtual reality this issue, so our Build It is a powerful, flashy gaming rig designed to bring VR experiences to life. That's PC-tethered VR, incidentally; no support for the likes of the shiny new Oculus Quest we review on page 80 (although Facebook is rolling out the Oculus Link software as we write this, which will allow Quest owners to use their headset for conventional tethered VR). If you've got a Rift or Vive, though, you'll want to hook it up to this system for latency-free, ultra-graphics VR adventures.

So, this is primarily a gaming system, but the focus is on virtual reality, including VR experiences beyond gaming, from virtual workspace attendance to architectural demos and digital travel experiences. Some of these can tax a PC, so this system needs powerful graphics, plenty of memory, and a competent CPU. VR gaming can be demanding, too, so a good VR-ready mobo is also a must. USB-C support and high-speed network connectivity are also useful, the latter in particular if you plan to play VR games online (such as multiplayer shooter *Pavlov).*

It's important not to skimp on cooling, too, but air cooling is fine as long as it's robust. We're not going to be overclocking this system, so overclock headroom on the CPU isn't really necessary, and the VR experience generally necessitates the use of headphones, so lots of fans aren't a problem. Of course, this is still a gaming machine, so we're going to be slapping some flashy RGB effects in there, so you can show off your rig and be the envy of all your non-VR-having peasant friends.

PHYSICAL REALITY

WHILE WE'RE GOING TO BENCHMARK this system against our usual selection of 1440p gaming PC zero-points, we're also going to try out some VR tests. To that end, we have an original Oculus Rift and an Oculus Quest equipped with Facebook's beta Oculus Link software. We're not including those in the price, though, as there's a few VR headsets that you could choose, and they're all priced very differently.

In terms of the physical hardware, we've got a Ryzen 7 3800X and a Zotac Gaming GeForce RTX 2070 Super, bringing octa-core CPU performance and high-end graphics together to make a gaming powerhouse. Cooling is handled by the surprisingly good Wraith Prism air cooler packaged with the 3800X, but there's the potential to spend more and snag a more powerful cooler. Those components are backed up by 16GB of high-speed Sniper X RAM, courtesy of G.Skill, all mounted on an MSI MEG X570 Unify motherboard. Don't forget to enable the A-XMP profile in the Unify's BIOS to make sure you're squeezing maximum performance out of that memory.

That's a mobo equipped with PCIe 4.0, so we're going to be using a fourth-gen M.2 drive: the excellent Corsair MP600 1TB. That means our transfer speeds will be as fast as it gets, making sure our games load ultra-quick. The MP600 comes with its own heatsink, but you'll want to remove that before getting started.

All that hardware is being powered by Fractal Design's awesome Ion+ 760P power supply, a competitively priced offering with a fully modular design; useful, considering that the case we're using comes with plenty of its own cables. That case is the XPG Battlecruiser, a beefy case that comes equipped with four of XPG's own 120mm RGB fans. It's got glass panels on four sides, magnetic dust filters, and numerous mounts for SATA drives. And lastly, as always, we'll be installing Windows 10 Home as our OS.

INGREDIENTS

PART		STREET PRICE
Case	XPG Battlecruiser	$180
Motherboard	MSI MEG X570 Unify	$300
CPU	Ryzen 7 3800X	$400
CPU Cooler	AMD Wraith Prism (stock cooler)	$N/A
Memory	16GB (2x 8GB) G.Skill Sniper X DDR4-3400	$130
GPU	Zotac Gaming GeForce RTX 2070 Super Amp Extreme 8GB	$580
PSU	Fractal Design Ion+ 760P	$128
SSD	Corsair MP600 1TB	$190
HDD	WD Black SATA HDD 6TB	$228
OS	Windows 10 Home 64-bit	$100
Total		$2,236

1 OPEN AND SHUT CASE

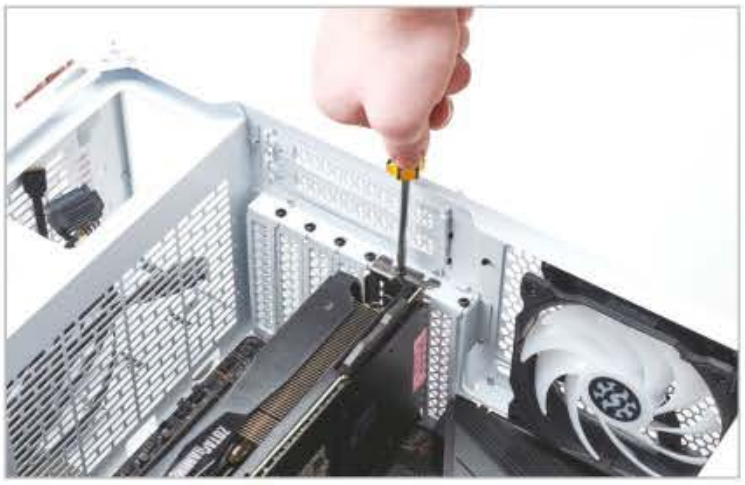
WE'RE STRIPPING DOWN THE CASE even more than usual. Both glass side panels of the Battlecruiser and the roof remove with thumbscrews; under the roof panel, there's a magnetic dust filter that lifts off, revealing the screws that secure the upper radiator bracket—as we're not using liquid cooling, we removed that, and the two plastic drive mounts behind the mobo plate. There's also an HDD mount on top of the PSU shroud, which can go.

2 GET IT TOGETHER

WITH ALL YOUR COMPONENTS READY, place the motherboard atop its box (or a dedicated workbench), and slot in the 3800X after lifting the metal retention arm. Next up is the memory; open the clasps, and fit the Sniper X sticks into slots A2 and B2. Simple. You need the Corsair SSD next, so pick a slot and plug it in after removing the relevant heatsink. Don't forget to remove the plastic cover from the sticky pad on the heatsink, too. Now mount the motherboard inside the case and screw it down. The rear I/O shield comes pre-attached, so that's one less thing to worry about, and the Battlecruiser's size means it's easy enough to fit the board beneath the rear case fan. Time to move on to the bigger components.

3 SUPER HERO

YOU NEED TO PUT THE CASE on its side for this section, as Zotac's 2070 Super is a massive three-fan affair. If the cables are in danger of getting tangled, you may want to temporarily replace the side panel covering the rear of the mobo plate for this step. Fit the cooler first, with a small glob of thermal paste on the CPU before the Wraith Prism slots down over it. Fit both clasps on either side of the AM4 mounting bracket, then snap the black plastic lever across to lock it in place. While we'll get to the bulk of the cable management later, plug the Prism into the mobo now, on to the CPU fan connector. For the GPU, remove the two blanking plates on the rear of the case, then slot the card into place before screwing it down with the same two screws from the blanking plates.



4 POWER TRIP

SET THE CASE UPRIGHT and remove the side panel again. The WD Black hard drive can go in next, slotting into the two-bay drive cage toward the front of the case. The plastic clasp that holds it in place is a bit flimsy, so be careful not to flex it too much. Now you can install the power supply. You need the PSU backplate, which you can find in the box of bits and pieces that comes with the Battlecruiser. Screw this metal oblong on to the PSU block, then attach all the cables you need: That's the two cables needed for the motherboard and CPU, the two-part GPU cable, and a SATA accessory cable for the HDD and fan lighting. Feed these through from the back of the case, then slot the PSU into place behind them, and secure it with four screws from that accessories box.

5 CABLE CAPERS

TRY TO KEEP THE DIFFERENT groups of cables separate, starting with the power cables. Going largest to smallest is the right way to go, so start with the 24-pin motherboard power cable, then work your way through the rest, routing them through the sharktooth rubber seals, and plugging them into the mobo. You don't necessarily need both connectors for the CPU; the second one simply provides more power for overclocking and demanding CPU-bound tasks. On to the front I/O cables; leave the fan and RGB connectors for now, instead sorting out the interface cables and USB connectors. Cable management is daunting in this case; some of these cables are quite long, so coiling them and tying them up behind the motherboard plate is the way to go.

6 LIGHTS ON

THE XPG BATTLECRUISER has a ton of cables to deal with, so we're dedicating some space to explaining exactly how these fan cables work. You're going to need to split your cables into three groups: fan power cables, gold-pin fan RGB cables, and front I/O RGB cables. As the Battlecruiser doesn't have a fan hub, we're ignoring that last set; we bundled them neatly and tucked them under the drive cage. The other two sets need to be daisy-chained together, leaving one connector for fan power and one for RGB lighting for all four fans. Make sure that the cable with the most slack is the final one to be connected, as that one needs to be plugged into the motherboard. This is the easiest way to set up the lighting, and gives you the default pulsing rainbow effect.

1 **We removed the top radiator bracket for this build, along with some unnecessary drive mounts.**

2 **XPG's 120mm case fans are many-bladed and relatively quiet, with some nice addressable RGB lighting if you're willing to buy a fan controller.**

3 **The Battlecruiser's lower shroud is inexplicably split into two parts for the PSU and drive cage.**

VIRTUALLY PERFECT

THIS PC MAXED OUT the "very high" quality meter on Valve's SteamVR Performance Test tool. Testing it with a regular Oculus Rift headset proved successful, as did playing conventional games. It's a big, powerful, flashy machine, well suited for VR gaming if money isn't a concern.

Sometimes it is, though, so there are a few things we might change if we started again from scratch. The XPG Battlecruiser is a pricey case, and has a lot of features we didn't use. We also might consider a smaller, cheaper HDD, as 6TB is a whopping amount, even for the dedicated gamer. If you think you can get by with the 1TB SSD, you might not even need to splash out on a hard drive. That SSD is a worthy inclusion, though, as the MP600 offers practically unparalleled transfer speeds for the fastest load times.

The Zotac RTX 2070 Super performed excellently. VR headsets tend to use esoteric resolutions, but the 2070 Super handled them fine. Latency was all but non-existent, and although benchmarking is difficult in VR, we were able to test a few games. *SUPERHOT VR*, *Beat Saber*, and *Space Pirate Trainer* looked awesome, reminding us that PC-tethered VR is still superior to standalone units like the Oculus Quest.

The Ryzen 7 3800X performed admirably, but we suspect that a 3700X would have had the same effect. This rig isn't designed for CPU-heavy tasks, and while VR is a bit more demanding on the CPU than regular gaming, there's not too much need for a particularly high-end part. The 3700X is $80 cheaper than the 3800X, and the difference in VR performance likely wouldn't be noticeable.

There's not much else we'd want to change for this build. It served its purpose well, but this could have been a cheaper system. We stand by our choice of memory; the Sniper X RAM from G.Skill is super-fast, which benefits our Ryzen processor a fair amount, and 16GB is more than sufficient for VR gaming. If you prefer your systems super-charged, 32GB would be fine, too, but it's an unnecessary addition.

The MSI mobo worked well, but any X570 board would've done the job. With PCIe 4.0, these boards tend to be a bit more pricey, but checking sales should net you a comparable board for a lower price. The same goes for the power supply, although the Ion+ 760P is great, and we wouldn't advise using anything other than fully modular PSUs for this build. All in all, this build achieved everything we wanted. Now, if you'll excuse us, we have *Beat Saber* high scores to beat (saber).

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	959	2,196 (129%)
CrystalDisk QD32 Sequential Read (MB/s)	3,442	4,989 (45%)
CrystalDisk QD32 Sequential Write (MB/s)	1,706	4,269 (150%)
Rise of the Tomb Raider (fps)	95	105 (11%)
Total War: Warhammer II (fps)	55	76 (38%)
Tom Clancy's Ghost Recon Wildlands (fps)	48	59 (23%)
3DMark: Fire Strike (Index)	9,128	12,376 (36%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i5-8400, 16GB (2x 8GB) of Corsair Vengeance LPX @ 2,666MT/s, an MSI GeForce GTX 1080 Armor, and a 500GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1440p at the highest graphical profile.

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The 3950X is essentially the 3900X with a few more cores.

AMD Ryzen 9 3950X

A multithreaded monster, great for content creators

BACK IN JULY, AMD launched a massive 7nm offensive in the CPU world. What can it do for an encore? More cores, more threads, and potentially higher clock speeds. The Ryzen 9 3950X really impresses in some areas, though it's not quite as awesome in other respects.

Let's start with the best use case, which is anything in the content-creation realm. With 33 percent more cores than the 3900X, and similar clock speeds, it's usually 25–30 percent faster. If you do video editing, 3D rendering, or any other task that can benefit from a 32-thread processor, you'll love the 3950X. For tasks that don't scale well to 16 cores, though, you're better off with a less expensive part. Even though the 3950X is nominally a consumer CPU, it costs a lot more. It's an HEDT CPU for the mainstream AM4 socket, priced 50 percent higher than the 3900X, which might not seem like that big of a deal for 33 percent more cores, but it doesn't include a cooler in the box. AMD recommends liquid cooling to get the most out of the 3950X.

Overclocking is a bit of an afterthought for the 3950X. You can probably do 4.1–4.3GHz on all 16 cores with the right cooling, but you'll give up maximum single-threaded performance in doing so. At stock, we saw all-core clock speeds hover in the 3,900–4,000MHz range, depending on the workload, and games would routinely run at 4,200–4,300MHz.

Gaming performance isn't the primary purpose of the 3950X. It can run games, but it does best when dealing with more difficult workloads that scale with core and thread counts, with clock speed being less of a factor. Compared to the 3900X, the 3950X is up to 33 percent faster in heavily threaded workloads. Overall, however, it's only 17 percent faster in multithreaded testing. Even with several different 3D rendering engines, video encoding, and cryptographic workloads, scaling beyond a 24-thread processor is difficult.

RIVAL RESULTS

Looking at Intel's CPUs, the competition isn't even close. The 3900X already beats the 9900K and 9900KS in multithreaded performance, although a few tasks, such as VeraCrypt AES, favor Intel's processors. With twice as many cores and threads, that's hardly surprising.

What about Intel's $2,000 18-core i9-9980XE? It does manage to hang on to the overall multithreaded performance crown, but by no means is it a clean sweep. It's 12 percent faster on average in multithreaded performance, but the 3950X does claim wins in Cinebench, POV-Ray, Blender, and Handbrake. It also leads in PCMark 10 results, which aren't quite as multithreaded-friendly. And it does all this while using substantially less power.

Where AMD's Ryzen 9 3950X shines is in the prosumer space. If you're doing serious work, but don't quite have a blank check to go out and buy a $5,000–$10,000 workstation, you can get roughly the same level of performance with the 3950X and save a few thousand. It's also generally a more efficient CPU than any of the workstation or HEDT parts, because the AM4 platform keeps things sensible.

And if you want to go HEDT, AMD has 32-core chips waiting in the wings, and it probably won't stop there. AMD has a great CPU portfolio right now, and we wouldn't be surprised to see Intel adopt something like AMD's chiplet strategy in future products. The 3950X would have been a far more costly product if AMD had tried to build the whole thing out of a single monolithic die.

We're still years away from most people wanting, let alone needing, 16-core processors at home. Heck, outside of playing the latest PC games, we can still do 95 percent of our work on a laptop from 2014. But while that laptop is fine for typing articles and minor image editing, it chokes on more complex tasks, like video editing. If that's the type of work you do on your PC, give the 3950X some serious consideration. **–JARRED WALTON**

VERDICT

8

AMD Ryzen 9 3950X

CORES GALORE Awesome multithreaded performance; sensible power draw; great for pros.

SNORE STORE Lackluster overclocking; no cooler included; expensive.

$750, http://amd.com

BENCHMARKS

	AMD Ryzen 9 3950X	Intel Core i9-9980XE	AMD Ryzen 9 3900X
Blender 2.80 Beta BMW (pps)	**5,719**	5,128	4,477
Cinebench R15 Single/Multi (Index)	**213/3,992**	198/3,765	210/3,160
POV-Ray 3.7.1 Single/Multi (pps)	**539/8,334**	464/7,978	522/6,639
PCMark 10 (Index)	**7,963**	7,428	7,285
Metro Exodus (fps)	90	90	**92**
Tom Clancey's The Division 2 (fps)	**148**	142	**148**
Total War: Warhammer II (fps)	90	79	**98**

Best scores are in bold. Our test bench consists of an Asus ROG Crosshair VIII Hero Wi-Fi (X570) motherboard, 16GB of G.Skill TridentZ RGB DDR4-3600, an Nivida GeForce RTX 2080 Ti, and a Gigabyte Aorus NVMeGen 4 1TB SSD. All games are tested at their highest graphical profile, ay 1080p.

SPECIFICATIONS

Base/Turbo Clock	3.5GHz/4.7GHz
Cores/Threads	16/32
Lithography	TSMC 7nm FinFET
Cache	64MB
Memory Support	DDR4-3200
Memory Channels	2
Max PCIe Lanes	16
Graphics	N/A
TDP	105W

Intel Core i9-9900KS

With 5GHz on all cores, it's the new gaming king

THIS A MILESTONE for Intel and CPUs, with the Core i9-9900KS officially being the first CPU that can do 5GHz on all eight of its cores, all the time. The Core i9-9900KS takes everything good about Intel's existing ninth-gen refresh, then cranks the dial up to 11, using binning to select the best chips and reach the lofty goal of 5GHz. Is it enough to maintain Intel's claim to the gaming throne? Yes, absolutely. The Core i9-9900K was already the fastest CPU in games, so tacking on 300MHz is only going to help.

At the same time, 300MHz more isn't going to come close to closing the gap between Intel and AMD's 12-core Ryzen 9 3900X in multithreaded workloads, never mind the 16-core Ryzen 9 3950X and third-gen Threadripper. Fifty percent more cores with relatively similar per-core performance, and only a 14 percent advantage in clock speed for Intel, means AMD unequivocally offers more total performance in the right applications.

Most people going out to buy a i9-9900K want the maximum performance possible, within reason, and with a good cooler, 4.7GHz shouldn't be a problem—and for the Core i9-9900KS, even 5GHz isn't a problem. Let's reiterate that bit about having a good cooler: Intel doesn't include any box coolers with its K-series CPUs, assuming that most enthusiasts plan to use something more robust. We can only guess what would happen if you tried a basic air cooler on the i9-9900KS, but it would either overheat and throttle, or overheat and crash.

Using a high-end motherboard with a good liquid cooler, temperatures weren't generally a problem. In fact, the 9900KS sample is clearly superior to our 9900K sample as it has lower idle power use by about 5W, and even running flat out at 5GHz, we didn't see temperatures go above 81 C in most workloads. The slower 9900K, meanwhile, topped out at 84 C with peaks of up to 92 C. With extreme liquid cooling, you can probably push the Core i9-9900KS up to 5.2–5.3GHz without overheating, but that's still a very small overclock. Ever since AMD became more competitive, Intel has been pushing clock speeds closer to the limit at "stock."

CHART TOPPER

As you would expect, considering the i9-9900K was formerly the top CPU in the gaming charts, the i9-9900KS is just a tiny bit faster. Overall, it's a 1.2 percent improvement over the 9900K, which means that even at 1080p ultra with a 2080 Ti, many games are still mostly GPU-limited. Basically, though, the top three CPUs are all effectively tied—no one is really going to notice the difference in gaming performance between the 9700K, 9900K, and 9900KS.

Moving our attention to application performance, the Core i9-9900KS doesn't look so potent. Many CPUs outperform the 9900KS in multithreading tasks, including pretty much all the Threadripper 2000 series, and the ninth-gen Skylake-X Core i9 parts. There's a catch, however: How many of these applications do you regularly use? Cinebench, POV-ray, and Blender all test 3D rendering performance. If you're not doing that sort of work, it's more of a theoretical benefit, rather than something immediately noticeable.

This is Intel's highest clocked CPU to date, finally hitting 5GHz on all cores without any serious effort on the part of the user. This is also a limited edition part, meaning just like the Core i7-8086K anniversary edition, it won't be on sale forever. It also still uses 14nm++ lithography, which is holding Intel back.

But even though it's built on yesterday's lithography, the Core i9-9900KS is more than fast enough for almost any non-professional workload. If you were looking at the Core i9-9900K before, the 9900KS is a barely noticeable bump in price for 3–6 percent more performance. It hangs on to the gaming crown as well, and will likely do so until at least the next generation of graphics cards arrives.

The i9-9900KS is largely the same chip as the i9-9900K. The main benefit is that it comes with some extra binning sauce. For slightly better performance, our 9900KS sample actually runs cooler than a lower clocked 9900K, and it still has a bit of overclocking headroom in a pinch. Right now, this is as good as it gets for gaming performance. **–JARRED WALTON**

VERDICT 9

Intel Core i9-9900KS

HIGH FIVE 5GHz on all cores; specially binned silicon; leads all CPUs in gaming performance.

DOWN LOW Slower in multithreaded workloads; limited overclocking potential; round six of 14nm.

$525, http://intel.com

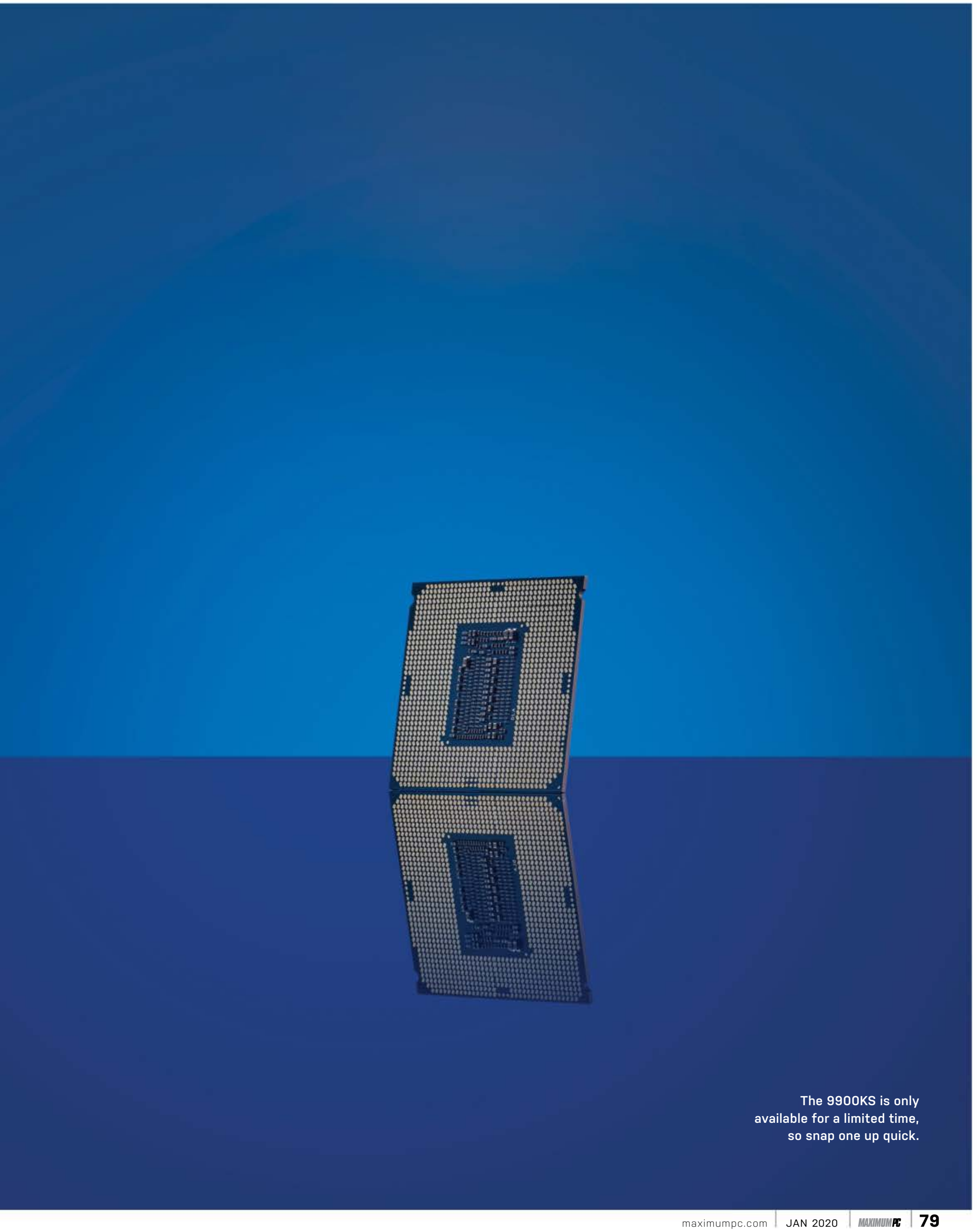
BENCHMARKS

	Intel Core i9-9900KS	Intel Core i7-8700K	AMD Ryzen 9 3900X
Blender 2.80 Beta BMW (pps)	3,281	2,247	**4,477**
Cinebench R15 Single/Multi (Index)	**221**/2,182	205/1,412	210/**3,160**
POV-Ray 3.7.1 Single/Multi (pps)	**629**/5,785	570/3,713	522/**6,639**
PCMark 10 (Index)	**8,316**	7,838	7,285
Metro Exodus (fps)	**96**	95	92
Tom Clancey's The Division 2 (fps)	**154**	152	148
Total War: Warhammer II (fps)	**112**	102	98

Best scores are in bold. Our test bench consists of a MSI MEG Z390 Godlike motherboard, 16GB of G.Skill TridentZ RGB DDR4-3200, an Nivida GeForce RTX 2080 Ti, a Samsung 970 Evo Plus 1TB SSD and a Corsair HX850 Platinum PSU.

SPECIFICATIONS

Base/Turbo Clock	4.0GHz/5.0GHz
Cores/Threads	8/16
Lithography	14nm
Cache	16MB
Memory Support	DDR4-2666
Memory Channels	2
Max PCIe Lanes	16
Graphics	Intel UHD Graphics 630
TDP	127W



The 9900KS is only available for a limited time, so snap one up quick.

Oculus Quest

A new standard for all-in-one VR

IS VIRTUAL REALITY A FAD? The debate rages within our own team, with the pro-VR camp still holding out for a killer app, while the detractors insist that it's doomed to pass by as another feeble attempt at gaming immersion. We're going to try to remain as impartial as possible for this review, looking at Facebook-owned Oculus's latest foray into virtual reality: the Oculus Quest.

One of VR's early stumbling blocks was the lack of portability and flexibility. Not only did earlier headsets require a wired connection, but they also needed a machine capable of powering VR games. Oculus's own first attempt at PC-less VR, the Oculus Go, wasn't powerful enough to be a real competitor to PC-tethered models. Other attempts involved glueing smartphones to your face, but if there's one thing we can agree on, it's that the less said about those, the better.

Enter the Quest. With an updated chip, the Snapdragon 835 from Qualcomm, utilizing Kryo 280 CPUs alongside Qualcomm's Adreno 540 graphics, this is the most powerful PC-free VR headset on the market. The Quest also has four exterior cameras that allow for proper positional tracking, similar to the original Rift. There's 4GB of memory, 64GB of storage, and two 1440x1600 OLED displays. The headset is a sleek black box with tough fabric padding and adjustable headbands. It's very comfortable, even for extended gaming sessions, and we had no issues with nausea while testing.

Hardware-wise, then, it's powerful for such a compact unit. It's never going to outperform a gaming PC, but Oculus is confident that the Quest will fill a gap in the market. Unfortunately, it takes a good two hours to charge the battery to full, and you'll be lucky to get more than the same amount of time from the battery if you play continuously, which is a real shortfall for serious VR gamers. The 6m charge cable means you can still play while charging, but that effectively stymies the "wireless" selling point.

Weak battery aside, the Quest does actually function well. The lack of a

connected PC means that the graphical quality is never going to blow anyone away, but VR titles that utilize more stylized, less realistic visuals still look awesome on the Quest's twin displays. Responsiveness and frame rates are very reliable, allowing for precision gaming in shooters and action games.

Your primary point of interaction in most games is via the two Oculus Touch controllers, funky handgrips with a large ring for motion tracking. They're the same hardware used with the Rift S, and they're just as effective now as they were then, feeling comfortable to use even for extended periods. They're probably the best VR controllers we've ever handled.

We really did have a lot of fun reviewing this. Fooling around in VRChat and *Beat Saber* led to some great office laughs; the fully wireless design made it easy to chop and change, swapping the headset between people, so everybody could have a try. The potential for family-oriented japes and party games is immediately evident, although we still have to question how appealing the Oculus Quest will be for serious gamers.

The graphical quality isn't bad, it's just not on par with PC-tethered headsets such as the HTC Vive or Oculus Rift S. *SUPERHOT VR* looks awesome, as does stylish adventure *Journey of the Gods.* It's worth noting that the Quest doesn't link directly to other platforms, such as Steam, confining you to the Oculus store. Granted, this ensures that the available titles are compatible with the Quest's hardware, but it ruins the product's potential as an upgrade for VR gamers in possession of a sizable game library.

It is possible to stream games on Steam via a PC, but it's a hassle, and there's still a risk of input lag. We'd love to recommend the Quest, and it does serve a good purpose as an entry-level VR headset for gamers without a powerful PC, but for £400, we can't quite do it. The Quest isn't bad, but it's not incredibly impressive. Even so, it's a decent introduction to VR, with some fun applications in a party setting. **–CHRISTIAN GUYTON**

VERDICT

7

Oculus Quest

HEROIC QUEST Great ergonomic controllers; comfortable headset; fully wireless.

QUESTIONABLE Poor battery life; no support for existing libraries; not particularly powerful.

$400, http://oculus.com

SPECIFICATIONS

CPU	Qualcomm Snapdragon 835
RAM	4GB
Graphics	Qualcomm Adreno 540
Storage	64GB (128GB model available)
Display	2x PenTile OLED 1440×1600 @ 72Hz
Connectivity	Bluetooth, Wi-Fi
Ports	USB Type-C, 2x 3.5mm headphone jack
Weight	1.26lb

The Quest retails at the same price as the PC-tethered Oculus Rift S.

HP ZBook X2

A quirky but powerful tablet workstation

WE KNOW WHAT you're thinking. Will you just look at those bezels? And that price. What the heck is HP doing with the ZBook X2, a $5,000 tablet that looks a decade old? But bear with us, because while this is a flawed device, it's also pretty special.

HP says the ZBook X2 is the world's most powerful detachable PC. A punchy claim at first glance, the detachable PC segment is in reality distinctly niche. In other words, the competition is fairly limited. Devices like the latest Microsoft Surface Pro 6 spring to mind, but despite being available with precisely the same Intel Core i7-8650U quad-core CPU as the ZBook, it isn't actually that comparable.

That's because of the ZBook's overall feature set and functionality, which is remarkable, if not quite always for the good. For starters, the ZBook offers not just discrete graphics but discrete workstation-class graphics, in the form of Nvidia's Quadro M620 GPU. If that sounds impressive, the somewhat sobering reality is that the M620 is based on the GM107 chip, and is thus not only based on the fairly ancient Maxwell architecture, but a low-end variant thereof with 512 shaders.

More impressive is the ZBook's 14-inch DreamColor display. It's not only 4K, but very high fidelity, with 10-bit color, and support for fully 100 percent of the Adobe RGB color space. It's also paired with a Wacom EMR input pen, offering 4,096 pressure-sensitive levels, and claimed ultra-low latency. Other major items as configured include fully 32GB of RAM, and a 1TB Toshiba NVMe SSD.

Arguably, however, it's the industrial design that really stands out. This thing feels as though it could survive an all-out nuclear holocaust. It's all-alloy, totally rock solid, and beautifully put together. Even the hinged kickstand feels impeccably engineered. The only obvious shortcoming in this area is the fact that the input pen doesn't have a home or slot in the chassis itself. HP simply provides a small wallet for storage.

If the build quality oozes professional intent, what to make of those bezels? Well, the point of them is to accommodate shortcut buttons either side of the display. HP's intent is to expedite navigating the dense menus and options in Adobe Creative Cloud applications, which can be awkward using an input pen. The result is a set of 12 buttons, six on each side of the display, which offer 18 preconfigured shortcuts customized for Adobe applications. Known as HP Quick Keys, the functions include quickly switching brush stroke size and hardness, turning touch on and off, pan and zoom, lock and unlock, and seeing a full-screen preview.

Finally, in terms of connectivity, the ZBook has two USB Type-C ports with Thunderbolt support, enabling two external 4K monitors, one USB 3.1 Type-A, HDMI 1.4, an SD card reader, and a headphone jack. There are also two webcams, front and rear, the front-facing camera with infrared functionality and Windows Hello facial recognition support. The side-mounted fingerprint scanner, meanwhile, provides an alternate method for biometric authentication.

As for raw performance, there are no real surprises. The Intel quad-core U series processor is a known quantity, and the ZBook's relatively chunky chassis means it performs to expectations. Likewise the Nvidia GPU and Toshiba SSD. In this age of relatively thin and light eight-core laptops, it's not going to set new standards for portable power, but it does offer real computing performance in a tablet form factor. What it doesn't offer is great battery life. Four hours is very poor indeed. Better battery life is possible using the integrated graphics, but that requires a trip into the BIOS, and comes at the cost of some functionality.

Ultimately, the ZBook is a niche product. For mainstream users, it offers poor value, but for content creators who do real work on the move, it's an intriguing and very high quality device. It's also been on sale for a little while now, so deals that undercut the fairly punitive official pricing should be available. **–JEREMY LAIRD**

VERDICT 8

HP ZBook X2

PULITZER PRIZE Stellar build quality; great features for pros.

AIRPORT TRASH Terrible battery life; very expensive.

$5,308, www.hp.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	561	575 (3%)
CrystalDisk QD32 Sequential Read (MB/s)	3,100	3,157 (2%)
CrystalDisk QD32 Sequential Write (MB/s)	557	1,005 (80%)
3DMark: Fire Strike (Index)	1,062	2,856 (169%)
Rise of the Tomb Raider (fps)	5	14 (180%)
PCMark 8 (Index)	2,543	3,634 (43%)
Battery Life: Movie Playback (Mins)	840	247 (-71%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our notebook zero-point is the HP Spectre X360, with an Intel Core i7-8565U, integrated Intel UHD Graphics 620, and 8GB of DDR4-2400. All games tested at 1080p at the highest graphical profile.

SPECIFICATIONS

Size	Intel Core i7-8650U
Graphics	Nvidia Quadro M620
RAM	16GB DDR4
Screen	14-inch 4K IPS
Storage	1TB NVMe SSD
Ports	2x Thunderbolt 3/USB-C, 1x USB A, HDMI, headphone, SD card
Connectivity	Intel Dual Band Wireless-AC 8265 802.11a/b/g/n/ac (2x2) Wi-Fi and Bluetooth 4.2
Weight	4.78lb
Size	0.75 x 14.35 x 8.94 inches

HP's latest ZBook tablet costs megabucks, but might just be worth it.

HP's DreamColor Z31x Studio Display is packed with features for serious content-creation pros.

HP DreamColor Z31x Studio Display

It ain't fashionable, but it is awesome

TOO MANY tech companies are slaves to fashion. HP certainly isn't guilty of that crime with its DreamColor Z31x Studio Display, a glorious 31-inch panel, with what HP describes as full "cinema style" 4K resolution. To say that the Z31x defenestrates the vogue for slim screen bezels would be the understatement of the eon. This thing is fat.

It is also, however, designed for serious professional productivity and content-creation work. So, quality, accuracy, and functionality are what matter, rather than superficial aesthetics. The Z31x has all of that in spades. For starters, those bezels are a function of its ability to fully calibrate itself. Top and center, HP has located a sensor that swings down on a motorized arm, allowing for full calibration.

What's more, the calibration tool can be set to run automatically. Similarly, the display can be configured to turn itself on and warm up on schedule. A nice trick, and indicative of the attention to detail HP has lavished on this screen. The same goes for other features, including a built-in KVM switch, dual DisplayPort inputs, two HDMI 2.0 sockets, a USB Type-C port with DisplayPort pass-through and charging power up to 60W, and an Ethernet port with support for configuring settings over a network via HTTP.

But it's the 31-inch IPS panel that really qualifies this screen as seriously special and worthy of true "pro" status. It all starts with that 4K "cinema" resolution. Specifically, that's 4096x2160 pixels, rather than the more typical 3840x2160 grid. It's thus slightly wider than the norm, with a 17:9 aspect ratio, and capable of showing 4K movie masters in full, which are encoded with 4,096 horizontal pixels.

Adding to its movie creation credibility, the Z31x can run at both 50Hz and 48Hz. The latter not only aligns with High Frame-Rate cinema content, it's also double the 24fps used by conventional theatrical releases, allowing for proper playback of major movie formats. The Z31x also has a true 2:1 pixel doubling mode, allowing 2K content to be displayed pixel for pixel, instead of via interpolation.

But that's just the beginning. Next up is true 10-bit-per-channel color fidelity and support for multiple color spaces. HP says the DreamColor Z31x is good for 100 percent of the sRGB space, 100 percent of BT.709, 100 percent of AdobeRGB, 99 percent of DCI-P3, and 80 percent of BT.2020, also known as Rec2020.

If all that sounds impressive, it is, but there's an obvious omission: This is not HDR-certified. But it is still gorgeous regarding image quality. With the full 4096x2160 resolution on a 31-inch panel, pixel density is fairly high, but it's the colors and accuracy you'll appreciate.

This screen looks bang on in native color mode and it's a cinch to jump into one of the numerous alternative calibrated color spaces via the OSD. There's loads of contrast on offer, too, and the viewing angles are as good as you're going to get from an LCD-based display. It's not eye-poppingly bright, but it's not supposed to be. What it's supposed to be is a seriously capable display for SDR content creation. It very much delivers on that remit.

The Z31x isn't cheap, but there are some very attractive deals available—as little as $1,800. At that price, you could almost argue it's a steal. **–JEREMY LAIRD**

VERDICT

9

HP DreamColor Z31x Studio Display

+ OSCAR WINNER Stunning panel quality; huge feature set for pros.

– GOLDEN RASPBERRY Not exactly sleek; not exactly cheap.

$2,999, www.hp.com

SPECIFICATIONS

Panel Size	31.1 inches
Panel Type	IPS, native 10-bit
Resolution	4096x2160
Brightness	250cd/m^2
Contrast	1,500:1
Pixel Response	20ms (full on/off)
Refresh Rate	48Hz, 50Hz, 60Hz
VESA Mount	100 x 100mm
Inputs	2x DP, 2x HDMI, USB Type-C

Several of the ports are concealed at the back of the M17.

Alienware M17

No "out of this world" jokes, please

ALIENWARE'S BEEN AROUND for a while, cranking out premium gaming hardware for almost as long as this reviewer has been alive. The M17 series of gaming laptops has been available ever since the company was purchased by Dell in 2009—high-end systems with 17-inch displays, and the latest in internal hardware. This new model of the M17 doesn't buck the trend: a recognizable design, top-notch components, and Alienware's signature branding plastered all over it.

As gaming laptops go, we have to admit that we like the design of this M17. The screen bezel is thin and black, and beneath it the speakers and fans sit below a hexagonal honeycomb mesh. It's surprisingly lightweight, too, and has quite a small profile when closed, as the screen hinge is mounted an inch or so into the base of the chassis from the rear edge, as opposed to on that edge.

The external hardware is hard to fault; the full-size keyboard is comfortable and responsive, with addressable RGB lighting for each key. The trackpad is perfectly fine, although plugging in a mouse makes more sense. In terms of other physical features, there's a port for a Dell-approved Noble Lock antitheft device, and some natty RGB lighting on the rear of the screen. The power button is, of course, a glowing alien face.

It's all about what's hidden inside that chassis, though. Four copper heat pipes and cooling fin stacks serve a 9th-generation Intel i7 CPU and a GeForce RTX 2080 graphics card—the slimmer, slightly less powerful Max-Q version, to retain the M17's slender profile. Two fans with liquid-crystal polymer blades channel air in through the top and bottom of the unit, then expel it through the rear and side vents.

Heat management isn't something this system does very well, though. The fans are quiet, to be fair, but the whole unit gets pretty hot after extended use, even for straightforward gaming. The six-core CPU frequently runs at around 50 C when the system is just idling, and leaps into the high nineties during complex rendering tasks. This is all the more confusing when you consider that the M17 apparently utilizes a handful of sensors for dynamic temperature control. It's a bit concerning, although the temperature spikes didn't lead to any noticeable performance issues in our testing, and this system isn't designed for workstation tasks.

Joining that RTX 2080 is 16GB of DDR4-2666 memory and two 512GB M.2 drives set up in RAID 0. As you might expect, the gaming performance is excellent (although those drives aren't particularly fast). The M17's display is a straightforward 1080p FHD panel; the maximum brightness is good, and the refresh rate goes up to 144Hz. It's a shame that this otherwise powerful system is limited to 1080p gaming, but it does provide a certain guarantee of performance by limiting gameplay to that resolution, and the screen is one of the better 1080p displays we've seen on a gaming laptop. The hinge, however, is a bit weak, making the screen feel flimsy.

There are virtually no games that this laptop can't run at 1080p ultra. Yes, some particularly GPU-battering titles might not be able to quite hit 60fps at those settings, but for the most part, this is an extremely competent gaming laptop. It packs an HDMI port and Thunderbolt 3 support for daisy-chaining higher resolution monitors, if you want to push its capabilities a bit further, although the hardware isn't quite good enough to reliably play games at 4K ultra settings.

This version of the M17 is a solid product; it isn't going to set the world alight, but it's a reasonably powerful piece of hardware, dressed up in an aesthetically pleasing chassis. Those familiar with Alienware's wares will know that you do pay a certain premium for its hardware, though, and the M17 is no exception—this model costs $2,700, a steep but not unreasonable price for what you get. Similar-spec laptops from the likes of MSI, Asus ROG, and HP Omen are a little more affordable, but there's a certain amount of style and promise provided by the Alienware brand. If Alienware has treated you well in the past, this laptop will only preserve your opinion. **–CHRISTIAN GUYTON**

VERDICT 8

Alienware M17

SPACE RACE Great gaming performance; good connectivity; appealing design.

LOST IN SPACE Expensive; screen feels flimsy; runs hot.

$2,700, http://dell.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,030	1,182 (15%)
CrystalDisk QD32 Sequential Read (MB/s)	3,374	3,231 (-4%)
CrystalDisk QD32 Sequential Write (MB/s)	2,530	2,163 (-15%)
3DMark: Fire Strike (Index)	13,610	18,156 (33%)
Rise of the Tomb Raider (fps)	92	95 (3%)
Total War: Warhammer II (fps)	62	81 (31%)
Tom Clancy's Ghost Recon: Wildlands (fps)	49	63 (29%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Acer Predator Triton 500, with an Intel Core i7-8750H, Nvidia GeForce RTX 2060 Max-Q, and 16GB of DDR4-2666. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	Intel Core i7-9750H
Graphics	Nvidia GeForce RTX 2080 Max-Q
RAM	16GB DDR4-2666 SDRAM
Screen	17.3-inch 1080p NTSC 72 percent color gamut @ 144Hz
Storage	2x 512GB PCIe M.2 SSD in RAID 0
Ports	HDMI, 3x USB 3.1 Gen 2 Type-A, 1x Thunderbolt 3, RJ-45, audio out, Alienware Graphics Amplifier port
Connectivity	Killer Wi-Fi 6 AX1650 (2x2), Bluetooth 5.0
Weight	5.8lb
Size	15.7 x 11.6 x 0.8 inches

MSI GeForce GTX 1650 Super Gaming X

Nvidia's budget GPUs just got a bit faster, or a bit more affordable

LIKE THE OTHER Super branded GPUs launched recently, the 1650 Super represents modest improvements to an existing part. In this case, the part is the TU116. That's a step up from the bottom Turing TU117 GPU used in the GTX 1650. Why the change? Simple: The TU117 lacks a few of the extra features found in its big brother. Specifically, it uses the older Pascal-era NVENC block that promises better quality than x264 Fast encoding via the CPU, with a minimal hit to frame rates, as well as GDDR6 support.

In terms of core specs, the GTX 1650 Super is a healthy jump in performance from the existing GTX 1650. It has 42 percent more GPU cores, and while it sticks with a 128-bit memory interface, the move to 12Gb/s GDDR6 means it has 50 percent more bandwidth than the 1650. There is one potential concern, though: VRAM. More specifically, the 4GB of GDDR6. It may have the same total bandwidth as the 1660, but with 2GB less memory, there are going to be situations where performance will be lower.

The MSI GTX 1650 Super we have in for review looks almost identical to the GTX 1650 Gaming X, but it's using the same board as the 1660 cards, which makes sense, as both use the same TU116 GPU. The 1650 Super has an extra DisplayPort output, compared to MSI's vanilla 1650 card. This card also comes with a factory overclock. In this case, it's not much to speak of: The boost clock is 1,755MHz, compared to the reference 1,725MHz. That doesn't mean it couldn't go further, and indeed often runs much higher than that, up to 1,900MHz, in fact.

Something else to note is that the GTX 1650 Super is a 100W TDP card, so it requires a six-pin power connector. If you have a PC that doesn't have any PCIe power cables available (which is the case for some budget pre-built PCs), you need to stick with the vanilla 1650.

Performance is pretty much what you'd expect: consistently around 30 percent faster than the regular GTX 1650. At 1080p with medium settings, it's nearly as fast as the 1660, but it falls off by 10 percent at 1080p with ultra settings, and 17 percent at 1440p with all the settings maxed out. Importantly, it manages to break 60fps in almost every game we tested at 1080p medium *(Metro Exodus* being the exception), but at 1080p ultra, it's far less certain. The overall average at 1080p ultra is 61fps, but only about half of the games break 60, while the other half range from around 40fps to 55fps.

Considering the GTX 1650 Super only costs $10 more than the regular GTX 1650, this is an easy recommendation. Budget GPUs certainly aren't the most exciting graphics cards around, but for people trying to game without spending a ton of cash, this is a great entry-level card that can easily run any current game. Just don't expect max settings and higher resolutions in every game, and beware of future games that could push beyond the capabilities of the GTX 1650 Super's 4GB of VRAM. If you can spend the extra $50 to $75, upgrading to a GTX 1660 Super is a better long-term decision. **–JARRED WALTON**

BENCHMARKS

	MSI GeForce GTX 1650 Super 4GB	AMD Radeon RX 580 8GB
Tom Clancy's The Division 2 (Avg fps)	**57/36**	52/33
Assassin's Creed Odyssey (Avg fps)	**38**/24	36/**31**
Far Cry 5 (Avg fps)	**76**/45	70/**50**
Shadow of the Tomb Raider (Avg fps)	64/41	**65/44**
The Outer Worlds (Avg fps)	**64/40**	49/34
Metro Exodus (Avg fps)	**42/32**	39/29
Total War: Warhammer II (Avg fps)	**55/40**	44/33

Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB of G.Skill DDR4-3200, a Gigabyte Aorus Gaming 7, and a 1TB Samsung Evo M.2 SSD. All games are tested at their highest graphical profile with AA turned on, at 1080p and 1440p respectively.

VERDICT **9**

MSI GeForce GTX 1650 Super

SUPERIOR Great overall value; much faster than the 1650; includes Turing NVENC.

POSTERIOR Only 4GB of VRAM; requires six-pin power.

$180, http://us.msi.com

SPECIFICATIONS

GPU	Turing TU116
Lithography	TSMC 12nm FinFET
Transistor Count	6.6 billion
CUDA Cores	1,280
Texture Units	80
ROPs	32
Core/Boost Clock	1,530/1,725MHz
Memory Capacity & Type	4GB GDDR6
Memory Speed	12GT/s
Memory Bus	128-bit

Cooler Master Silencio S600

Silence falls once again as Cooler Master returns

YOU MAY BE FAMILIAR with Cooler Master's Silencio series. As the name suggests, this is the Taiwanese manufacturer's noise-damping line of cases, and the S600 is the latest and (perhaps) greatest iteration. Not everyone needs such a case, but if you're rocking a noisy, powerful system—particularly an air-cooled overclocked build—you might want a case that stops it sounding like a force-10 gale with a throat infection.

The S600 arrives alongside the smaller S400 (for Mini-ITX fiends), offering a refinement to the original Silencio design, with an overall improvement of the quality and available features. It's a pretty straightforward upgrade; if you own an older Silencio, such as the 650 or 452, you probably don't need this.

If you don't already have a sound-damping case for your PC, though, the Silencio S600 could be for you. It's a seriously robust case; the outer frame is solid metal, with both side plates fitted with mass-loaded vinyl padding to mute any internal noise. However, that means it's heavy. It's not a particularly large case, but it weighs over 18lb without any additional hardware inside it, so you need to be wary of that.

All that weight does serve its purpose well, though; the S600 is very sturdy and has plenty of internal space. There's a full PSU shroud, under which also lurks a bay with space for up to three HDDs or SSDs. The case comes with some nifty clips for mounting drives in the bay slots, there's also mounting positions for additional drives, and even a slot for a 5.25-inch optical drive at the front of the case, behind a hinged steel panel.

The S600 is positively brimming with features. The front I/O includes an SD card reader, internal rubber seals for neatly routing cables, and there's a top air vent that can be swapped out to another sound-damping panel if you value quietness over airflow. There are also two case fans, both Cooler Master's own Silencio FP 120mm models. Much like the case itself, these are designed with silence in mind, with RPM control and rubber antivibration pads. There's room for extra fans, too.

Remember that door panel we mentioned? It has a thick, spongy layer of noise-canceling foam on the inside, and snaps shut with a hidden magnet. The hinge can be unscrewed, and the door has a reversible mount that allows it to be opened from either the left or the right. It's easy to make the switch, and could be beneficial if you want to position your system against a wall. The hinge is inexplicably made of plastic, though, unlike its steel surroundings, and we fear it could snap off after extended use.

In terms of aesthetics, the S600 is a brutalist monolith of matt black metal. That's about it; there's very little going on in terms of appearance here, but that's only a deal-breaker if you happen to like your systems decked out with all the subtlety of a Deadmau5 concert. A windowed version is also available at a marginally higher price, in case you want to show off your expert cable-management skills. However, this does presumably come with a decrease in the sound-damping capabilities of the case.

We're genuinely racking our brains to find some negative points for this review. The lack of USB-C support on the front I/O is a missed opportunity, and the expansion slots at the rear have a bulky, annoying exterior cover. It's good value, too, at only 100 bucks. You really do get a lot for your money with this case.

As a final point, we should briefly compare it to some other noise-canceling cases available on the market right now. Corsair's Carbide series comes in at around the same price as the new Silencio, while others, such as Be Quiet!'s Silent Base 601, are touch more pricey. Most of these don't offer support for an optical drive, though. The S600 is an awesome choice of case if you need a quiet but flexible system, with a modest exterior appearance. **–CHRISTIAN GUYTON**

VERDICT 9

Cooler Master Silencio S600

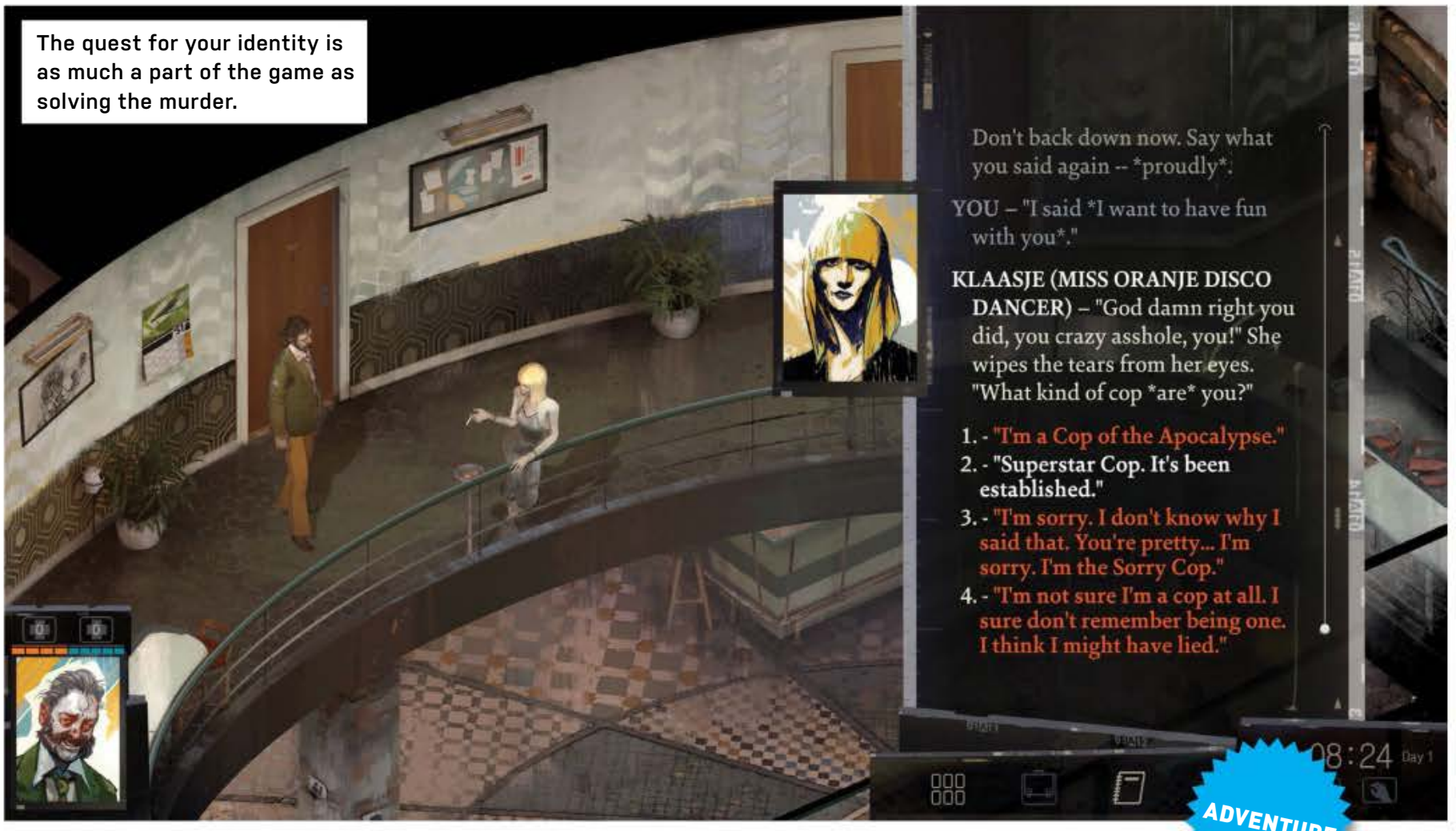
SILENCE Excellent noise-canceling; powerful case fans; great drive support.

CACOPHONY No USB-C support; slightly flimsy front door hinge.

$100, http://coolermaster.com

SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	ATX, mATX, ITX
Colors Available	Black
Window Available	Yes
3.5-Inch Support	4
2.5-Inch Support	5
Radiator Support	280mm front, 240mm roof, 120mm rear
Fan Support	2x 140mm front, 2x 140mm roof, 1x 120mm rear
Dimensions	8.3 x 18.1 x 16.9 inches
Graphics Card Clearance	15.7 inches


Don't back down now. Say what you said again -- *proudly*.
YOU – "I said *I want to have fun with you*."
KLAASJE (MISS ORANJE DISCO DANCER) – "God damn right you did, you crazy asshole, you!" She wipes the tears from her eyes. "What kind of cop *are* you?"
1. - "I'm a Cop of the Apocalypse."
2. - "Superstar Cop. It's been established."
3. - "I'm sorry. I don't know why I said that. You're pretty... I'm sorry. I'm the Sorry Cop."
4. - "I'm not sure I'm a cop at all. I sure don't remember being one. I think I might have lied."
08:24
Day 1

The quest for your identity is as much a part of the game as solving the murder.

ADVENTURE

Disco Elysium

A text-heavy RPG with a strong sense of the bizarre

A TOP-DOWN RPG/adventure game! In 2019! Well, sort of. *Disco Elysium* might be viewed from above, and its police detective plot might sound like something Sierra On-Line could have produced, but this is a postmodern game for postmodern times, and it isn't afraid to let things get weird.

Your tie is talking to you, for one thing. Waking, naked apart from your socks, on the floor of a squalid hotel room in some ghastly 1970s alternate reality, the world's worst hangover has pummeled your memory into a blank slate, perfect for character creation. There's a murder to solve—somebody, probably you, has allowed the corpse of a hanged man to remain in a tree at the back of the hotel for several days; it stinks, and you feel so tender you barf—if you manage to get dressed, that is. Getting your tie from its resting place on the ceiling fan is tricky if you don't have enough points in Physical.

While you can roll your own character from the off, there are some ready-made ones waiting for you. It doesn't matter which you choose, as it won't stay that way for long. Every piece of clothing you acquire boosts some skill in some way. There's often a sting in the tail, though, as a stat that protects your character from the effects of drugs may lead to you abusing them, or one that detects lies may lead to paranoia. You've been in the hotel for a few days, misbehaving, and the guests give you clues as to what sort of person you are. Don't like what they say? Deny it and bounce in another direction.

With 24 skills, if you tally up the sub-skills, everything is a test of one or another. Even combat, when it occurs, is more a test of dice rolls than of pixel-accuracy or weapon level. Equipping the right clothing can give you enough of a stat boost to pull success from the jaws of defeat, and failed tasks can be re-rolled under the right circumstances.

The game has a rather beautiful hand-painted aesthetic, the character portraits a particular highlight, but even in 4K on a huge screen, you're never going to get away from the text. There's reams of the stuff, constantly scrolling up the right-hand side with every thought your character has and every microdecision you make. Choose the Sensitive character archetype, or otherwise boost the Inland Empire skill, and you're treated to the thoughts of inanimate objects, too. The Thinker, with his Encyclopedia skill, constantly uncovers new facts about his environment. It's a good thing there are no tests of player skill—you'd fail every one because you were still reading about the environment. You have a partner, too, who fills in the blanks with yet more text.

Luckily, the reams of text just allow the quality of the writing to shine through. However you develop your character, there's a line that will make you smile. As a police procedural, even one starring such a complete human disaster as the protagonist, the game could be dry and feel too bound up in rules. Thankfully, you never feel this, as intelligent choices in setting and the characterization of those around you make every choice seem valid.

If this is the start of a new golden age of top-down detective adventures, we're here for that. And even if it's a one-off, we're happy to have seen it take flight so successfully. Unforgettable. **–IAN EVENDEN**

VERDICT 9 KICK ASS!

Disco Elysium

DISCO Acres of painted graphics and a book's worth of quality writing.

PROG Not a game to be played fast; can occasionally feel too obscure.

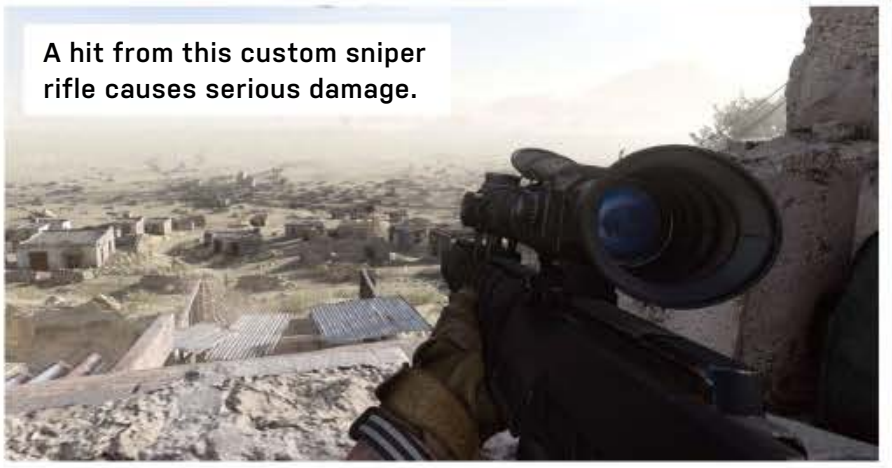
RECOMMENDED SPECS i7 or Ryzen 7; 8GB RAM; GTX 1060 or equivalent.

$40, http://zaumstudio.com, ESRB: Not rated

© ZA/UM

You are often a small part of a larger operation.

A terror sequence in London features civilian deaths and suicide bombers.



A hit from this custom sniper rifle causes serious damage.

Night-time levels showcase the new lighting tech.

FIRST-PERSON SHOOTER

Call of Duty: Modern Warfare

More military shooting from the masters of the genre

YOU KNOW WHAT you're getting when *Call of Duty* goes back to its "roots" in the fourth game. You get three years of Infinity Ward's full attention, with additional help from High Moon, Beenox, Raven, and Sledgehammer. It had better be good—and luckily it is.

While we get yet another plot about American intervention in a Russian invasion of a fictional country somewhere in that space where Turkey meets Iraq, it's also a game of beautifully recreated moonlit alleyways, night-time walks in the forest, abandoned motorbikes, and a battered PC case with the single best rendering of a Molex power connector we've yet seen. Its use of darkness is sublime, enabling you to be the terror in the night before deftly turning the tables.

It sees the return of Captain Price who, amusingly, has the same facial hair as the protagonist of *Disco Elysium,* but few of his other hang-ups. Price is ruthless and clinical, tossing hostages padlocked into suicide vests off ledges, rather than have their explosion kill innocents, and rocking the most ridiculous night vision goggles. He's a good man to have on your side, even if you do spend a lot of time following him around. In fact, there's a lot of following in general, including a stand-out part in which, as a small girl, you follow your brother through war-torn streets.

Such breaks from the *COD* norm never last for long, but then nothing does. For a glorious two minutes, you launch remote-control planes laden with explosives into Russian helicopters. There's a short reprise of *Death From Above,* in which you use a helicopter to splatter soldiers who were making your life hard just moments ago. There's the requisite sniping level in which you must take bullet drop and wind speed into account, but it's over the moment you use your rifle to hammer bullets into the engine blocks of trucks.

It keeps up this pace, from thunderous assaults on aircraft hangars that wouldn't have been out of place in 2017's *WWII,* just with different guns, to midnight house clearances that couldn't come from anywhere else. It's a game that knows its identity, on its own and as part of a series-within-a-series. It pulls the same trick *Infinite Warfare* managed, of standing out in an otherwise samey genre, but does it while being ostensibly the same as other games, not by taking Jon Snow to space. It even manages *Half-Life 2's* trick of directing your gaze where the devs want you to look, an otherwise unremarkable trek down a zig-zag staircase showing events outside timed perfectly with your descent.

The new engine is part of that distinctiveness. Even without ray tracing, it looks good. The lighting, in particular, deserves heavy praise, justifying the decision to set so much of the game in the dark. Character models are sharp and believable, their mo-capped movements fluent. The hair-rendering technology produces such great beards and stubble that a female resistance leader seems strange for her lack of whiskers. Performance is good, too, with 4K not out of the reach of RTX 2060s and upward.

The best *Call of Duty* for a long time? Probably. But also a rattling good story, with multiplayer that will keep you coming back for years. **–IAN EVENDEN**

VERDICT **8**

Call of Duty: Modern Warfare

DUTY Great graphics, sound, and performance; non-stop pace.

SHOOTY Retreads of *COD* greatest hits; some controversial content.

RECOMMENDED SPECS i5-2500K/Ryzen 5 1600X; 12GB RAM; GTX 970/R9 390.

$60, http://callofduty.com, ESRB: M

© ACTIVISION

LAB NOTES

CHRISTIAN GUYTON, STAFF WRITER

VR Struggles

I desperately want to love VR. Why can't I?

I THINK VR is a lot of fun. I've fooled around with most of the big-name headsets (I'll get my hands on a Valve Index eventually), and most games I've played have been genuine fun. Some games just work in VR; the moment I first dived into space combat sim *EVE: Valkyrie* was a revelation. I can't properly describe the mix of emotions I felt upon looking down and seeing my own newly space-suited body gripping the controls of my ship, lasers glinting off the cockpit glass, while missiles subtly followed the movement of my head.

And yet, when I look at the industry, I can't help but feel disappointed. *Half-Life: Alyx* is a single pinprick of light, a hopeful glimpse into a world of glorious, immersive, big-budget VR games, but I'm afraid that it won't be enough. Developers understandably don't want to commit too much to VR projects when the format is still struggling to achieve any significant mainstream success. It might be a jealous, entitled thing to say, but I want more! I think of all the game worlds I'd love to explore in VR—from a fresh perspective like *Alyx;* not going back into *Skyrim* for the 90th time, Todd—and I'm practically salivating.

Look, BioWare, honestly, I just want to talk.

The deep, expansive universes of *Warhammer, Bioshock,* and *Titanfall* would be glorious in VR. I want to pilot a towering mech around a battlefield swarming with other players, to lop off some orc heads with a weighty swing of my sword. Let me explore the most beautiful settings in gaming, like Rapture or Hyrule, or crawl through creepy vents aboard *Dead Space's* USG Ishimura. And lastly: EA, please let BioWare bring back *Mass Effect* as a VR shooter-slash-dating-simulator. I have no shame. I'll pay good money for that.

ALAN DEXTER

Executive Editor

The notion of the "killer app" is overused in this industry, and it often only has real meaning after the fact—it can be easy to look at a console, or a specific market, and pinpoint the killer app that lead to a piece of hardware taking off. It doesn't have to be one thing—there are several reasons the iPhone redefined cell phones. The PC, though, has had a number of moments in its evolution that have seen it survive, but there hasn't been a killer app.

There's a couple of tech areas that are struggling, and maybe they need that game-changing release. VR is clearly in need of something to lift it from the drab hole it finds itself in, and there may well be light at the end of the tunnel in the form of *Half-Life: Alyx*—if you want a killer app, you can't ask for much better than Valve to swing to your rescue. I personally suspect this one release will sell more VR hardware than anything before.

The other area that could do with some big-name love is real-time ray tracing. We've had a handful of decent games with ray-tracing effects—*Control* being star so far—but there's nothing that makes me think, "I need this." Bizarrely, the ray-traced spin of *Minecraft* has me most excited, where the basic graphics of this much-loved classic stand out as an obvious improvement. Is it a killer app? Time will tell.

© BIOWARE

Editors' Picks:
Digital Discoveries

Senior editor, Jarred Walton, and hardware staff writer, Joanna Nelius, kick back and enjoy the simpler things

RED DEAD REDEMPTION 2

Who doesn't want to roam the plains of the Wild West, staring off into the beautiful sunset? Forget the bank robberies and other hijinks, *Red Dead Redemption 2* on PC is the definitive way to play, and it looks stunning. Or at least, it can.

A heads-up before you even think about cranking all the settings to maximum: Your PC almost certainly can't handle the truth. And the truth is that even at 1080p with an RTX 2080 Ti and a Core i9-9900KS, you're going to see dips below 60fps—and that's before enabling 4xMSAA. I recommend sticking to high quality settings, which look nearly as good, and allow for a relatively steady 60fps or more with a 2060 Super or faster GPU. Also, turning down reflections and volumetrics doesn't affect image quality much, but can boost performance.

There's a lengthy single-player story that can take 100 hours or more if you start wandering off the beaten path. Or you can stick with *Red Dead Online* and lose yourself in the company of friends and strangers for the next year or more. If you're like me, and don't bother with consoles, come join the fun on the best gaming platform around. Long live the PC.
$60, www.rockstargames.com

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RAZER KRAKEN ULTIMATE

I've been spending time with Razer's Kraken Ultimate headset. One of its features is THX support—the audio quality assurance system that has been synonymous with the motion picture industry since the 1980s. While other headsets tout 7.1 virtual surround sound, the Kraken Ultimate takes 7.1 further with its THX compatibility. Not only is this the first headset I've worn that fits the contours of my head, but it also sounds fantastic.

To get 7.1 to work, just download and activate the driver from the Razer website. The bass is warm and deep without creating an uncomfortable vibration inside your ear canal, and the treble is smooth and balanced alongside the bass. There's no rattling, even with the volume cranked to the max. The binaural response is also good, which makes it easy to tell where approaching footsteps or gunfire are coming from in a game. The only downside is the mic, which takes some adjusting to increase the volume of your voice, but then I still haven't come across a headset mic that I like better than my Blue Yeti.
$130, www.razer.com

G-Technology ArmorATD 2TB

ARE YOU THE OUTDOORSY TYPE? Western Digital's subsidiary G-Technology has you covered. The ArmorATD is an external hard drive designed to survive the harsh conditions of even the most desolate wilderness, perfect for hikers, photographers, and extreme sports enthusiasts. If you need durable tech that can survive the elements, there aren't many rugged HDD manufacturers, and Western Digital's name carries a promise of quality.

The ArmorATD has all the features you'd expect from a super-rugged HDD, and more. The exterior is solid aluminum, with internal shock mounts and a rubber sleeve that ensure protection against drops and whacks. It's also crush-resistant up to 1,000lb, according to G-Technology, so it could likely even survive a landslide. They're so confident about the ArmorATD that they offer a three-year warranty, too.

The rubber armor also includes a seal to ensure protection against dust and rain, protecting the USB-C port (which also supports Thunderbolt 3). It's compatible with Windows and MacOS, and comes with a USB-C cable and USB-C-to-USB-A adapter to make it truly plug-and-play. It comes in 1TB, 2TB, 4TB, and 5TB models, and isn't too expensive. For comparison, the 2TB model we've had to play with only costs 10 bucks more than Seagate's 2TB STEA2000400 Black external hard drive, which has none of the resilient features of the ArmorATD. **–CG**
$90, https://shop.westerndigital.com/g-technology

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Durable PCs
> Revolting Readers
> Global Pricing

Lasting Forever

I run a small tech company and have subscribed to your magazine for years. I can't honestly say I read every magazine and every article, but I do find your build challenges very helpful. I don't have time to research all the new hardware, and articles like yours simplify my research when it comes time to build custom machines.

However, I may have missed it, but I was wondering if you have any articles on builds that use more durable yet budget oriented hardware, that can run 24/7 for years without breaking down? I know the cost will increase, but I still find it hard to mix and match those kinds of parts. Any suggestions you have will be helpful!

–Edward Sheaffer

STAFF WRITER, CHRISTIAN GUYTON, RESPONDS: I've not addressed this before, but it's actually less about which components you use and more about how you treat your system. If you're running a PC 24/7, the thing that's gonna kill it is dust buildup. Make sure you regularly open up the case and give it a good blast with compressed air; go with cases that have magnetic dust filters, and clean them regularly. Keep that system in a room that stays cool, out of sunlight, and is on a hard surface above the floor—no carpets!

With regard to which parts, most well-known brands generally do build their components to last these days—just make sure you're getting good warranties, in case a part does give up the ghost. Avoid moving parts where possible; that means SATA SSDs instead of HDDs, motherboards without built-in fans, and integrated graphics on the CPU, rather than a GPU with its own fans. Case fans are cheap to replace; GPU cooling, not so much.

Lastly, it's a good idea to stick with a low-power build. Get a high-quality Gold or Platinum PSU at a relatively low wattage, and eliminate power use from the system wherever possible to minimize temperature buildup. In the same view, a good CPU cooler is a must; after dust, overheating is the biggest thing to watch out for. Get a motherboard with good power management features, and avoid RGB lighting like the plague!

Graphics Revolution

It's time for a video card pricing revolt! I have been a faithful subscriber since the days of *boot* magazine, and am well versed in *Maximum PC's* "cost is no issue" mantra, but we've hit a point where it has become absurd where video cards are concerned. Specifically, the RTX cards. It's time for a protest via keeping our dollars, to rein in Nvidia's ego and pricing a whole lot of notches.

I just retired my trusty (then high-end) 2012 build, with a Core i7-3770K, a P8Z68-V PRO/GEN 3, 16GB 1,866MHz DDR3, and a 1080 Ti. I upgraded the video card about every two years, always going with the 80 or 80 Ti versions, starting around $500 for a 580 GTX, and ending up at $680 for the 1080 Ti FE. I just built a new higher-end system last week that uses a Gigabyte Auros Ultra X570 mobo, a Ryzen 7 3800X, 32GB 3,600MHz DDR4, a 1TB 970 EVO M.2, two 3TB Seagate HDDs in RAID 1, a Corsair H100i Pro, three Aerocool 40mm silent fans, a Cooler Master H500p Master case, an EVGA 850W modular Platinum PSU, and Win 10 Home 64-bit full version. (Thanks for pointing me to PC Part Picker in the recent system builder parts pricing article.)

Total cost for all that spicy PC goodness? About $58 more than a 2080 Ti RTX FE card costs, which, for the record, is more than double what the 1080 Ti FE cost new. An entire high-end PC, minus video card, for roughly the same cost as just a video card. It's frankly absurd. I looked at benchmarks and reviews on the 2080 Ti, and since it only sports 9–22 percent better performance than my 1080 Ti, depending on title, and costs double what my 1080 Ti did, and as much as the entire rest of my build, I opted to skip this generation, and keep my 1080 Ti, which happens to be tearing through everything with aplomb on ultra settings with this new build.

It is absurd what Nvidia is charging for the RTX cards, but as long as

↘ submit your questions to: comments@maximumpc.com

people dive in, paying these outrageous prices, it will charge what it likes. I say it's time for a wallet protest, to let Nvidia know enough is enough, and let's get back to realistic pricing. A high-end video card should not cost as much as an entire high-end system. Take the reins, *Maximum PC,* and lead the revolt! Anything costing double what it should for only 9 percent more performance only gets a 5 review, not a 9 Kick Ass!

–B.J. Koho

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: This may surprise some, but I agree. The higher echelons of Nvidia's Turing cards are frankly terrible when it comes to value for money—the GeForce RTX 2080 Ti still costs over $1,100, and yet can't guarantee 60fps playback in all games at 4K, which for us is a deal-breaker. I was rocking an overclocked 2080 Ti for most of the year, and while it was nice in theory to max the settings for every game, there were enough moments when the frame rate dropped below that to leave a bad taste in my mouth. Throw in the fact that there has only been a handful of ray-tracing titles, and that they definitely don't run smoothly at 4K, and you are left wondering why you've dropped so much cash on it.

That said, it's easy to see why this has happened: Nvidia has no competition at the high end, and so a) it can charge pretty much want it wants, and b) this breathing space has enabled it to invest in ray tracing while it has the leeway to do so. If things were much more competitive, it would have been a much more risky proposition. An extension of this latter point is that we'll need to wait for the second- or third-generation iterations of ray-tracing hardware before it really becomes widespread. Nvidia has actually done a relatively good job of getting developers to try out ray tracing, and it's definitely a technology for tomorrow, if not quite today.

As for your particular setup, you have a decent system, and the GeForce GTX 1080 Ti is a great graphics card for the vast majority of today's games. We still use them in the office, and while we do sometimes hanker after the new-shiny-thing, we're not at a critical point just yet. And to be fair, it isn't like we gave the 2080 Ti a Kick Ass review, so we called that one pretty well.

[NOW ONLINE]

RED DEAD REDEMPTION 2 SETTINGS GUIDE, BENCHMARKS, AND MORE

Red Dead Redemption 2 is finally here on PC, and it has a ton of graphics settings to play with. It also has stability issues and requires a fast CPU (or a workaround to help eliminate stuttering)—it's been a rough launch on PC for many players. Your PC might be in need of an upgrade to run it well. There's also the important choice between DX12 and Vulkan graphics APIs, not to mention performance across popular CPUs and GPUs. It's a lot to cover, so let's get to it.

Looking at the PC features, the list of graphics settings is good, if perhaps a bit overkill. Resolution support is good—we were able to select widescreen, ultrawide, and doublewide resolutions, as well as old-school 4:3 stuff, such as 1024x768. Except *RDR2* doesn't properly handle those in full-screen mode. Borderless windowed and windowed modes are fine, but in full-screen mode, *RDR2* just stretches whatever your monitor's native aspect ratio is to the chosen resolution.

Read the full article: https://bit.ly/2DjxZOd

Dollar Differences

I read with great interest your review of the Acer ProDesigner BM320, on page 81 of the December 2019 issue. You had two American flags, which fundamentally I do not object to, but you also mentioned England, where the price is lower. Not so here in Canada. Maybe in a corner you might display a Canadian flag, as I believe there's a number of faithful readers here. And speaking of this very issue, I put together your "$500 Build It Challenge." Your final price was $590 US; not so here—total ingredients price: $785. A premium must be paid for a much smaller market. So sad!

–Murray McCullough

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Unfortunately, the economies of scale often mean that the US gets the best deals, while "smaller" territories tend to be hit with elevated pricing. Sadly, we can't really print pricing for every territory where *Maximum PC* is sold, as we're sold worldwide, but we do try to highlight where there unusual disparities, as was the case with the Acer screen. Just be thankful that you don't live in Australia, where the smaller market and costs of transportation often mean that components can be double what they are in the States.

Home Security

While doing research for a home security system, I realized I couldn't use my go-to resource for computing. In fact, I don't recall an article in the mag on the subject going back to the days of *boot.* So many wired systems are IP cameras with the same concerns as a monitor, but in reverse. And they're connected to an NVR, which is just a specialized PC. I'm curious: Why no content on this category of computing?

–Brett Pichon

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: A few members of the team have experience of setting up and using security cameras, both NVR and DVR systems, but we've not done much in the magazine because it is a bit niche, and also it's always felt as though it's an industry that needs to settle down a little on the standards front—we're also seeing a shift as the Internet of Things takes hold, with the hope of making everything somewhat easier to use. Even so, it is probably high time we produced a feature on the state of play, and we'll pencil it in for a future issue.

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THE BUILDS

BUDGET

INGREDIENTS

PART			PRICE
Case	BitFenix Nova TG		$70
PSU	Corsair CX450 80+ White 450W		$50
Mobo	MSI B450M PRO-M2 V2	NEW	$72
CPU	AMD Ryzen 5 2600		$120
GPU	Asus GeForce GTX 1660 Super 6GB	NEW	$230
RAM	8GB (2x 4GB) Patriot Viper 4 Blackout @ 3,000MT/s	NEW	$33
SSD	120GB Adata SU650 SATA III	NEW	$20
HDD	1TB Seagate Desktop ST1000DM003		$30
OS	Ubuntu Desktop Linux 18.04.3 LTS 64-bit		$15

Approximate Price: $640

UNFORTUNATELY, the price of our Budget build has risen a little this issue. The BitFenix case rose by $10, and the trusty ASRock B450M motherboard we've used for ages has finally dropped off sale, so we're swapping it out for an MSI B450M mobo at a slightly higher price. We managed to save a little bit of money elsewhere, snagging Patriot's slick Blackout edition of its tried-and-true Viper 4 memory for an absolute bargain at $33. It's a pretty straightforward sidegrade, keeping the capacity and speed the same for this build, but saving us $4. We did the same thing with the SSD, swapping the HP model for an Adata SATA drive to save $4 again. The SU650 isn't particularly exciting, but neither was the part it replaced; it's a SATA drive, it's cheap, and it's effective. We looked into improving the processor, too, but the Ryzen 5 2600 is still on sale at $120—an excellent deal.

MID-RANGE

INGREDIENTS

PART			PRICE
Case	Fractal Design Meshify C		$85
PSU	500W EVGA 500 BT 80+ Bronze	NEW	$50
Mobo	ASRock X570 Phantom Gaming 4	NEW	$149
CPU	AMD Ryzen 5 3600X		$234
Cooler	AMD Wraith Spire		N/A
GPU	XFX Radeon RX 5700 8GB	NEW	$330
RAM	16GB (2x 8GB) Corsair Vengeance LPX @ 3,200MT/s	NEW	$60
SSD	500GB Seagate FireCuda 520 M.2 PCIe SSD	NEW	$133
HDD	1TB Seagate Desktop ST1000DM003		$30
OS	Windows 10 Home 64-bit OEM		$100

Approximate Price: $1,171

WE'VE HAVEN'T MANAGED TO SAVE any money on this build either. Rats. A few minor changes were made in the name of keeping the price down, mostly just brand changes; switching over to Corsair Vengeance LPX memory, for example. We've also swapped to an XFX model of the Radeon RX 5700 GPU, and a new motherboard—moving away from Gigabyte, we're now using an ASRock X570 Phantom Gaming 4. We needed to keep that X570 format, because the biggest change here is a shift over to a shiny new PCIe 4.0 M.2 drive, the FireCuda 520 500GB from Seagate, taking advantage of the Ryzen 5 3600X's fourth-generation NVMe support for super-fast data transfers. We also made a tiny change to the power supply. Did you spot it? We went from an EVGA 500 BR to an EVGA 500 BT. If you can tell the difference in practical performance, we salute you.

UPGRADE OF THE MONTH

500GB SEAGATE FIRECUDA 520 M.2 PCIE SSD

Slowly but surely, more and more manufacturers are putting out PCIe 4.0 M.2 drives. First came Corsair and Gigabyte, swiftly followed by Patriot, Team Group, and XPG (the latter of which is featured in the Turbo build this month). The latest, though, comes from drive production giant Seagate Technology, in the form of the gaming-oriented FireCuda 520 SSD. The 500GB model is, at the time of writing, one of the cheapest PCIe 4.0 drives currently on the market, so if you want crazy transfer speeds without having to spend a ridiculous amount of money ($400 isn't an uncommon price for high-capacity PCIe 4.0 SSDs), this is the way to go. **$133, http://seagate.com**

© SEAGATE

MERCIFULLY, we managed to save a bit of cash on our Turbo build! Although our choices of PSU and motherboard rose slightly in price, a switch to Gigabyte's Turbo Edition RTX 2080 Super saved us 20 bucks without sacrificing that sweet gaming performance, and the NZXT H700i case dropped in price by a gentle $4. A particularly pleasing change for this build was the RAM; we stuck with G.Skill, but moved over from Sniper X to the Ripjaws V series, which cost us $25 less, and also has a lower CAS latency for improved performance. It's nice when things work out, isn't it?

With a bit more cash to play with, we decided to get ahead of ourselves in a different area. While the Threadripper 2950X doesn't support PCIe 4.0 for speedy new M.2 drives, the next generation of Threadripper does, so we're going to prep our Turbo build with XPG's Gammix S50 1TB, a fourth-gen NVMe SSD that'll be ready to unleash hell with ultra-fast transfer speeds when Threadripper 3000 CPUs arrive, and we inevitably shove one into this build.

We'd love to change some more things, but there's plenty of stuff coming in the near future that will be exciting to see, primarily for this high-end build. We contemplated going down to a 240mm radiator AIO cooler, but if we're going to be using upgraded parts in the near future, we'll stick with the powerful and good-value ML360 from Cooler Master, for that crisp triple-fan cooling setup.

For more of our component recommendations, visit www.pcgamer.com/hardware/buying-guides/

INGREDIENTS

PART		PRICE
Case	NZXT H700i	$175
PSU	850W Corsair RM850 80+ GOLD	$125
Mobo	ASRock X399 Phantom Gaming 6	$240
CPU	AMD Threadripper 2950X	$680
Cooler	Cooler Master MasterLiquid ML360 RGB 360mm AIO	$140
GPU	Gigabyte GeForce RTX 2080 Super 8GB Turbo Edition NEW	$700
RAM	32GB (2x 16GB) G.Skill Ripjaws V Series @ 3,600MT/s NEW	$125
SSD	1TB XPG Gammix S50 M.2 NVMe NEW	$180
HDD	2x 3TB Seagate BarraCuda Compute	$160
OS	Windows 10 Home 64-bit OEM	$100
Approximate Price:		**$2,625**

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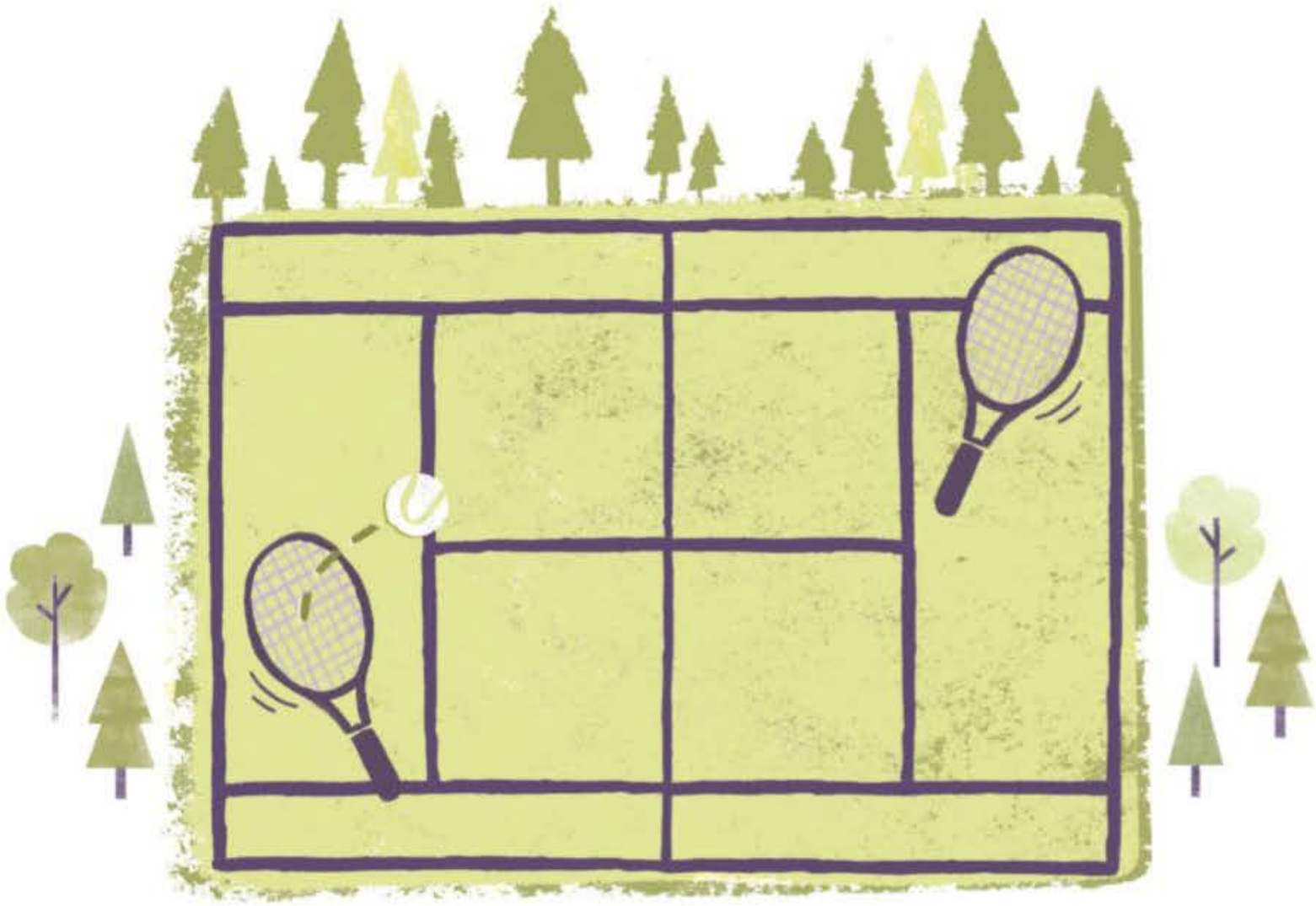

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UNFAO, Global Forest Resources Assessment 2005-2015

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